

FOCUS

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NASA IS ABOUT TO CAPTURE A FRAGMENT OF ANCIENT ASTEROID.
WHAT THEY BRING BACK COULD SHOW US HOW LIFE BEGAN.

PLUS HOW WE CAN PREVENT ASTEROID ARMAGEDDON

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OIL

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WEARABLES TAKE ON AUTISM

The tech tapping into the minds
of autistic children

INDIGENOUS SCIENCE

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Parasitic genes leapt
from insects to humans



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The bug that causes stomach ulcers could help treat allergies →p27

WELCOME



Four years ago, the European Space Agency (ESA) achieved something that seemed impossible. It caught a comet. It was an idea first conceived in the 1970s, but it wasn't until some 30 years later that, in March 2004, scientists from across the continent launched Rosetta on a decade-long journey. Over the next four years, the spacecraft would swing around Mars, and then Earth three times, before stopping in deep space just beyond Jupiter. There Rosetta waited, in deep hibernation, for its rendez-vous with comet 67P/Churyumov-Gerasimenko. Then in 2014, ESA woke Rosetta from its slumber and sent it chasing after 67P. Eventually, in a manoeuvre that would make Evel Knievel blush, Rosetta's lander, Philae, bounced down onto the surface of 67P, discovering that it was unlike anything on Earth. The data it gathered, much of which has surprised scientists, is being pored over today.

By September 2016, Rosetta had travelled 3.6 times further away from the Sun than the Earth is, and the craft was starting to find it difficult to harvest sufficient solar energy. ESA crashed Rosetta into the slab of rubble and ice it had spent 10 years chasing.

Now NASA and JAXA (the Japanese space agency) want to show what they can do. The two agencies have conjured up daring missions to capture and return a sample of an asteroid. Both want answers to questions: did asteroids deliver the materials needed to light the spark of life on Earth? And how could we divert an asteroid that could end life as we know it? Find out how they'll get their answers on p40.

PS – We're heading to the brilliant Bluedot Festival over 21-22 July. If you spot me, come and say hi!

Daniel Bennett

Daniel Bennett, Editor

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COLIN BARRAS

Western science has a lot to learn from indigenous people. Science journalist and palaeobiologist Colin uncovers what we're learning. → p66



LEWIS DARTNELL

Two missions are about to visit two separate asteroids. Astrobiologist Lewis reveals what we might discover about the origins of life. → p40



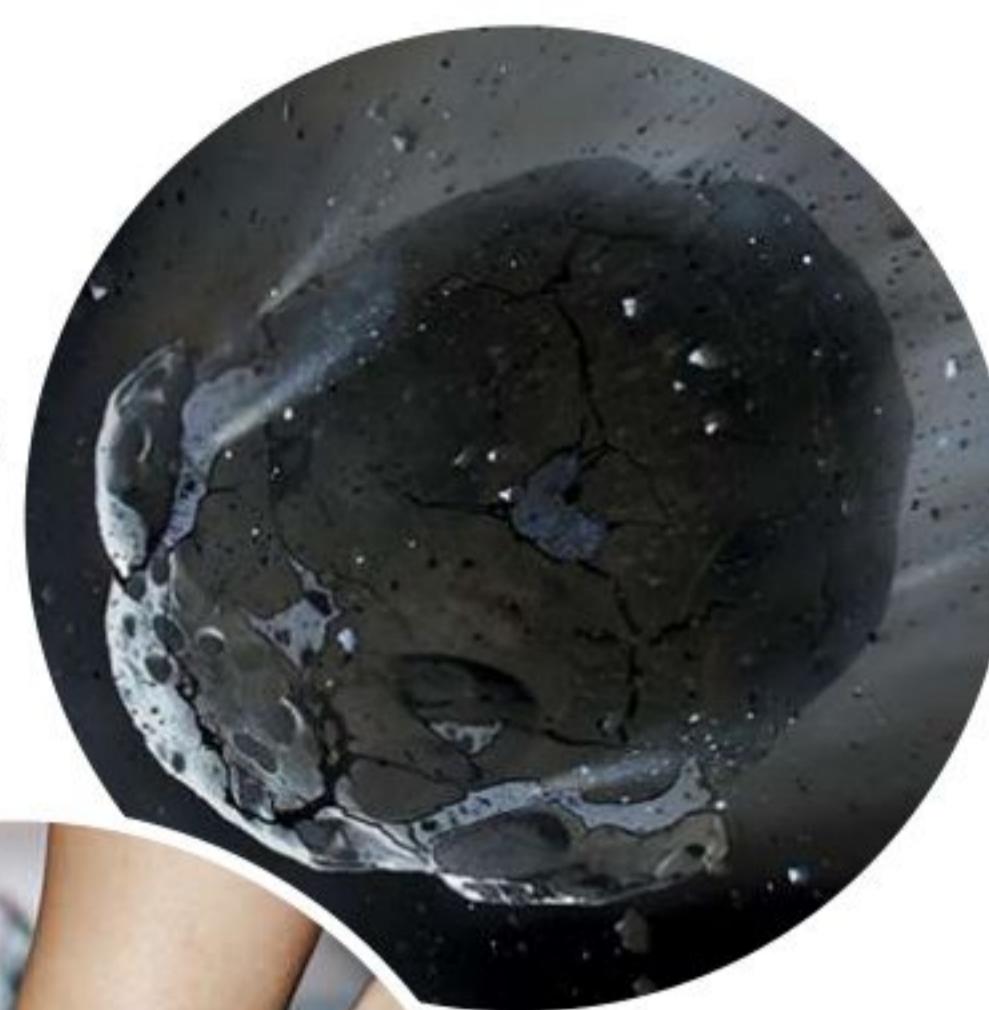
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Happy 60th birthday, NASA! Spaceflight historian Amy takes a look back over the space agency's most iconic moments. → p56

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I've been tying my shoelaces wrong my whole life →p84



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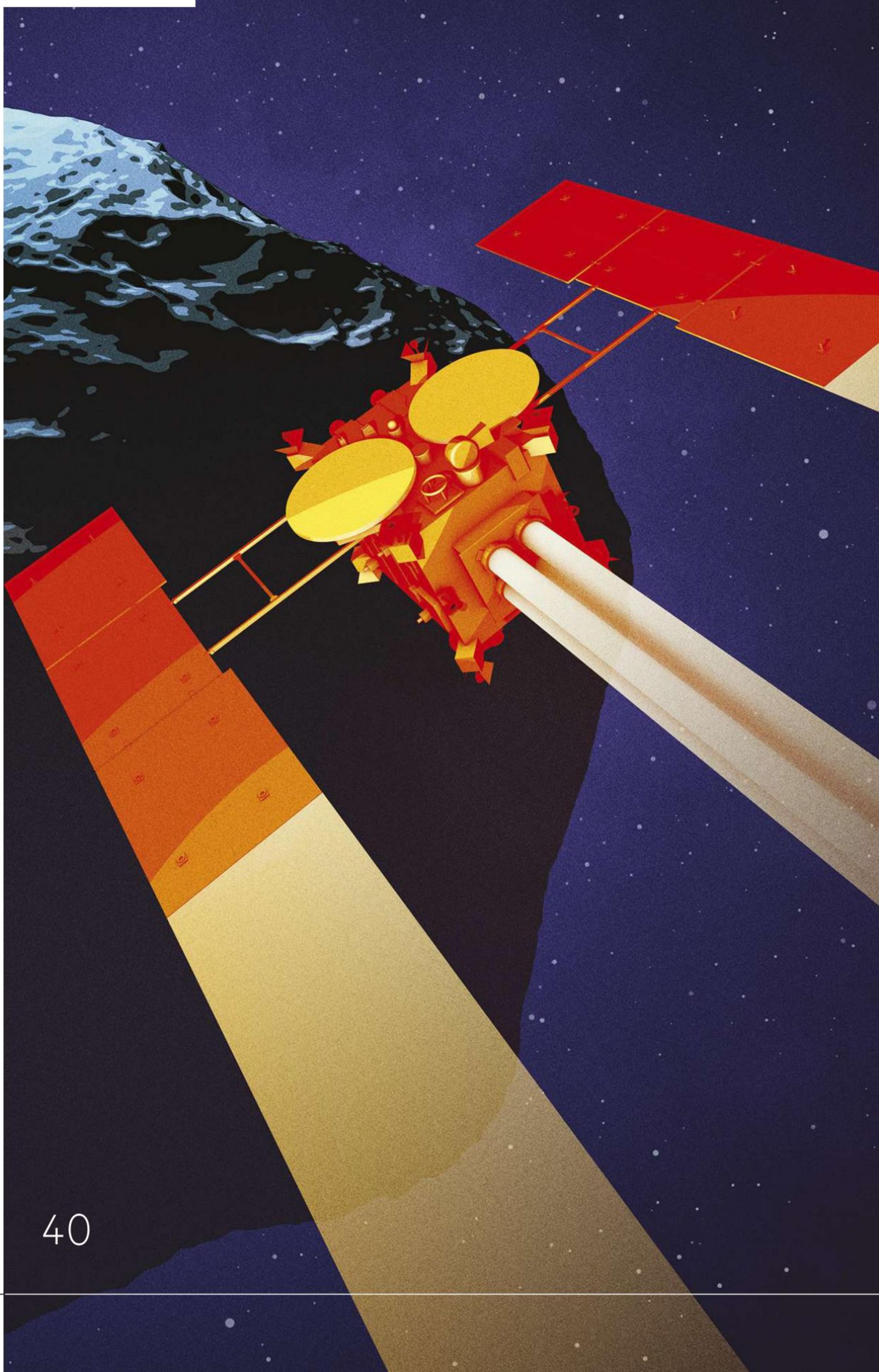
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Helen Pilcher talks to BBC presenter Dr Alice Roberts about skeletons, swimming and *Strictly Come Dancing*.

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60 years of NASA

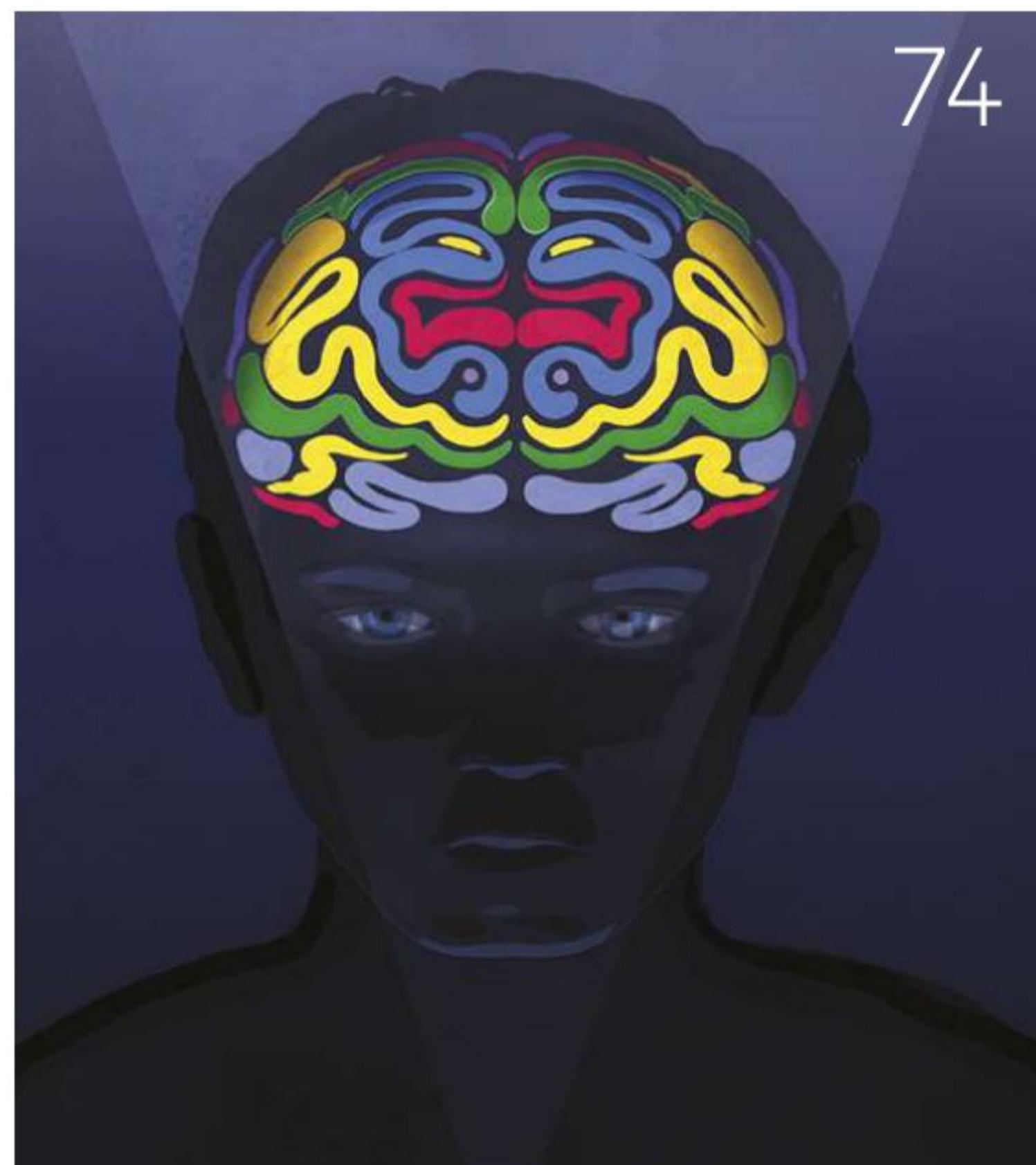
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WANT MORE?

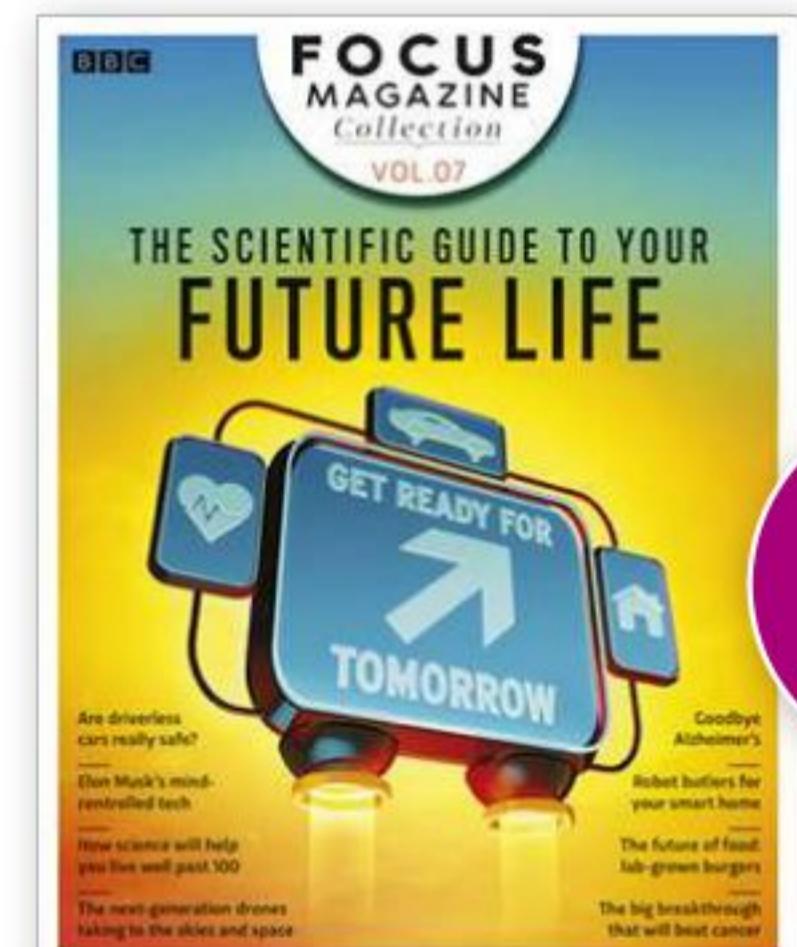
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SPECIAL ISSUE



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An aerial photograph showing a massive, dark, and textured lava flow from a high vantage point. The lava is thick and appears to be moving slowly. In the lower right, a two-lane asphalt road with a yellow center line cuts through the lava field. Sparse, dry vegetation, including small trees and shrubs, is scattered across the lava flow and the surrounding terrain. The overall scene is one of a powerful natural event. A small, white, rectangular box with a thin black border is positioned in the upper left corner of the image.

EYE OPENER

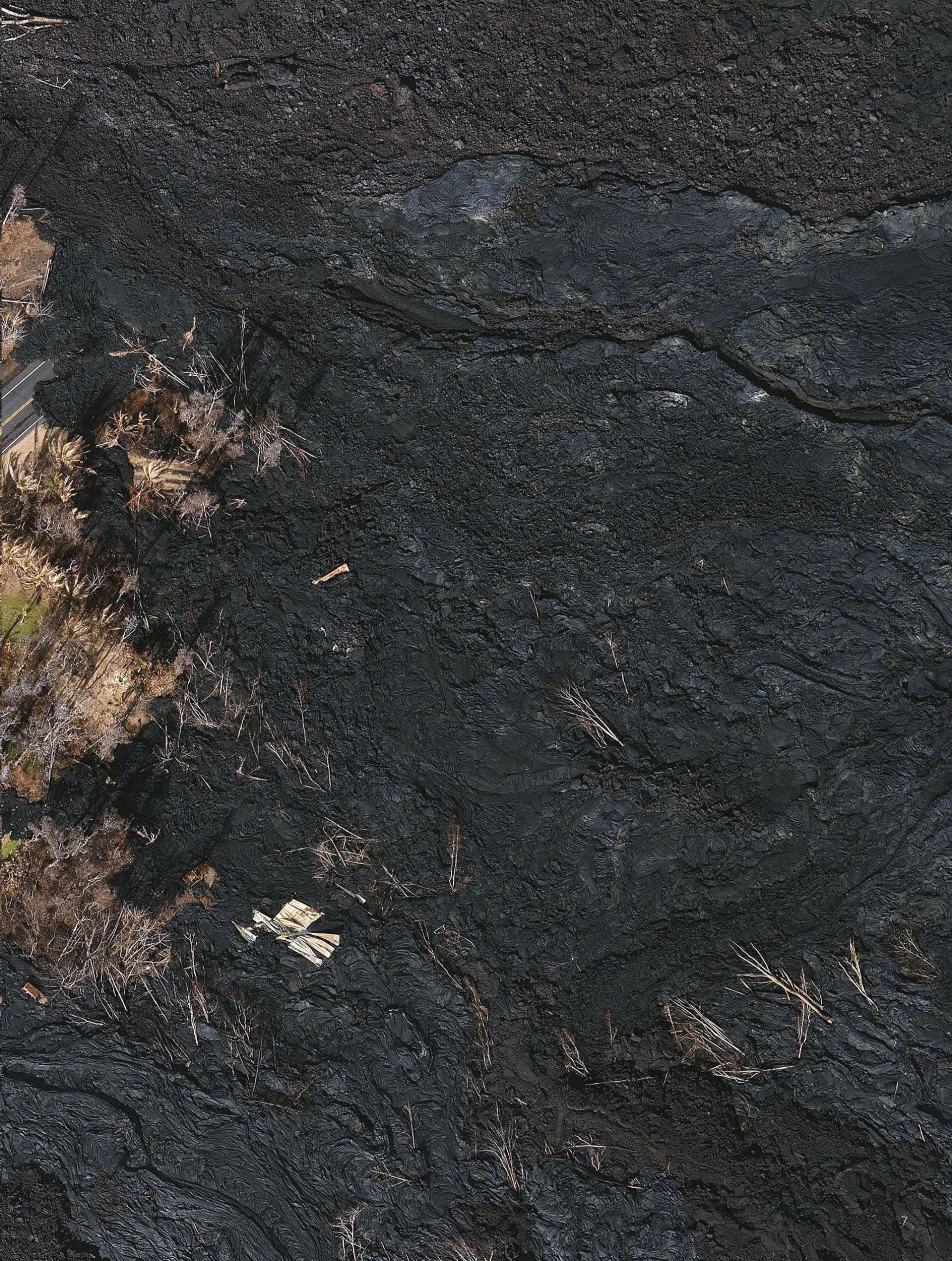
Island in the lava stream

PĀHOA, HAWAII

The small exposed hillcrest seen here is surrounded by recently cooled lava that's been spilling across Hawaii's Big Island since the Kilauea volcano started erupting on 4 May. As well as tumbling out of the volcano's crater, the lava's been seeping through fissures in the ground. While the lava is moving slowly, the long duration of the eruption has resulted in a flow that extends for 10km and has destroyed 700 homes. So far, 10,000 people have been displaced.

It's actually the latest phase of a far longer eruption that's been going on since 1983, making it the longest continuous eruption known to us. Hawaiians are so accustomed to the island's volcanic activity and the presence of lava that they have a word, 'kipuka', for spots like this one pictured. Kipuka roughly translates as 'openings' or 'islands'

OLIVIER GRUNEWALD







EYE OPENER

Fury unleashed

VOLCAN CALBUCO, CHILE

This breathtaking combination of lightning and volcanic eruption took place in Chile in 2015, and is known as a dirty storm. In a dirty storm, the black plume billowing out of a volcano's crater carries red-hot ash and rock fragments that jostle and collide with each other as the smoke spews upwards. These collisions create static electric charges that build until they can longer be contained, at which point they're discharged as bolts of lightning that arc upwards through the plume.

A 2016 study of dirty storms over Sakurajima volcano in Japan suggested that volcanic lightning could indicate the size of a volcano's ash cloud and could therefore be used as a basis for providing air quality warnings to the surrounding area.

FRANCISCO NEGRONI

REPLY

Your opinions on science, technology and *BBC Focus*

MESSAGE OF THE MONTH

T. rex trifles

I read the editor's letter in the July issue and I can relate to his fears of being chased by a *T. rex* – it's bound to be happening in one multiverse or another. But rest assured any dinosaur coming after you from the Cretaceous period would be so out of breath that you could run rings round it. Fingers crossed.

Pat MacDonnell, Ireland

Hah. That's a good point. These days the air lacks the kind of oxygen levels *T. rex* would have been accustomed to in the Cretaceous period. In fact, if they had managed to build a *Jurassic Park* (or *Jurassic World* as the new films suggest) it'd just be full of puffing, wheezing dinos, struggling to get around. Sadly, I don't have the same excuse... – **Daniel Bennett, editor**

Playback error

I was fascinated to read last month's issue and to find about congenital aphantasia (Summer, p10). Such a contrast to those who can run back a video of events that have happened to them.

Eric Middleton, North Yorkshire

Doing the dirty

Use a dishwasher rather than use the sink? Ridiculous! You forgot to include the environmental cost of dishwasher raw materials, construction, transportation and disposal. When handwashing the dishes I: rinse/soak first in cold; don't change the water; rinse off in cold; use the water on the garden. Please be realistic (scientific?) in your comparisons!

Andy Vowles, via email

WRITE IN AND WIN!

The writer of next issue's *Message Of The Month* wins **four books from the Ladybird Expert series**.

The enlightening books cover artificial intelligence, genetics, the Big Bang and plate tectonics, and have each been written by some of the most outstanding communicators in their fields. penguin.co.uk

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Must... eat... editor... but... can't... breathe

I absolutely agree, it is possible to handwash dishes in such a way as to use less energy than a dishwasher. The comparison I drew in the article comes from a study that looked at the *typical* way that people wash dishes, not the optimal way. In addition, it was based on US survey data, where there seems to be more of a tendency to leave the tap running. The feature was trying to show ways that you can save energy while being lazy, but of course there are much bigger gains to be made if we are prepared to put in a bit of effort! – **Luis Villazon, BBC Focus contributor**

Benzene basher

I read your article on NASA finding complex organic matter in Martian rock with interest, only to find out they hadn't really found complex organic matter. You



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mentioned benzene, but this only has 12 atoms. Personally, I will get excited when they find organic compounds that contain over 100 atoms – now that's starting to get complex. Another thing you sometimes hear is scientists claiming to find the building blocks for life outside of the Earth, but have they? Have they found an information storage method like RNA? Have they found something resembling a cell wall? Not as far as I know. It just all seems rather exaggerated to me.

I think we need to get things into perspective. For example, with regard to planets around other stars, finding a planet with liquid water is exciting from a discovery point of view, but finding

a planet with liquid water and an oxygen atmosphere is exciting from both a discovery and an evidence for life point of view.

Andrew Cirel, via email

Poor old benzene. — **Daniel Bennett, editor**

I'm your Venus, I'm your fire

I read the question about climate change and whether Earth could become another Venus (Summer, p81) and thought it worth mentioning that the presence of CO₂ is a minority driver in maintaining such extreme temperatures as Venus suffers. The sheer pressure exerted by the immensely dense atmosphere is what generates the majority of the heat (see Fredric Taylor's fearsomely detailed *The Scientific Exploration Of Venus* for more). Obviously increased evaporation of the oceans could see Earth's atmospheric pressure rise if temperatures were to rise very significantly, but I don't believe any models show this as likely in the foreseeable future. This letter isn't intended to undermine the focus (no pun intended) on CO₂ here on Earth, lest I be misunderstood!

Simon Bartlett, via email

Plastic-eating microbes might not save us from pollutants, says Eddie Racoubian



Bugging out

Bugs that eat oil? Has anyone thought this through? (May, p21) It sounds like the ultimate terror plot to destroy the modern world. A superbug that eats our highways and turns the world's oil wells, reserves, tanks and gasoline into muddy water would be nature's ultimate revenge.

George Robinson, Alabama, US

Have you seen the weather lately, George? I think nature's already paying us back.

— **Daniel Bennett, editor**

Plastic headaches

In your June issue, I was relieved to learn that we found bacteria that eats away plastic. But here's what comes to mind: our main problem is the plastic that's produced is not fully recycled. Without proper segregation and collection schemes, plastic will still end up in the seas, thus rendering possession of an enzyme useless. Moreover, from your previous issue, there was mention of only one plastic pollutant. But what about BPA, PFC, etc? Do we have Pac-Mans for these too? Sadly, I think a wonder enzyme will not clean our seas yet.

Eddie Racoubian, Lebanon

BBC Focus

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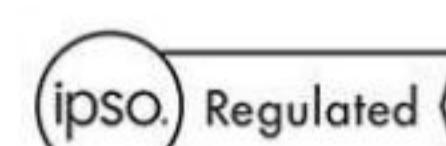
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MUSEUM



DISCOVERIES

DISPATCHES FROM THE CUTTING EDGE

AUGUST 2018

EDITED BY JASON GOODYER



Australian monotremes (platypuses and echidnas) do not seem to have the L1 jumping gene

BIOLOGY

'PARASITIC' GENES THAT JUMPED FROM ONE SPECIES TO ANOTHER WERE KEY DRIVERS OF EVOLUTION

Genes can leap across species, and not just from parent to offspring. Now, scientists are finding out just how pivotal this process could be

"THINK OF A JUMPING GENE AS A PARASITE. THEY COPY AND PASTE THEMSELVES AROUND GENOMES, AND IN GENOMES OF OTHER SPECIES"

The world's largest study of 'jumping genes' – small pieces of DNA that can copy themselves throughout a genome and can transfer between species – suggests one jumping gene, called L1, played a vital role in the evolution of mammals.

Researchers at the University of Adelaide traced jumping genes across 759 species of plants, animals and fungi. They found that cross-species transfers, even between plants and animals, have occurred much more frequently throughout evolution than once thought.

"Think of a jumping gene as a parasite," said Prof David Adelson, who led the research. "Properly called retrotransposons, they copy and paste themselves around genomes, and in genomes of other species. How they do this is not yet known, although ticks or mosquitoes, or possibly viruses, may be involved – it's still a big puzzle. This process is called horizontal transfer, differing from the normal parent-offspring transfer, and it's had an enormous impact on mammalian evolution."

L1 entered the human genome around 150 million years ago. In humans it has previously been associated with cancer and neurological disorders. Understanding the inheritance of this element is important for understanding the evolution of diseases, the researchers say.

The researchers found that the L1 element is abundant in many other plants and animals, as well as fungi. However, it is not present in the



ABOVE: The L1 jumping gene can hop between animals, plants and fungi

BELOW: Frogs and bats share the BovB jumping gene, which may have been transferred via parasites that feed on blood

Australian monotremes (platypuses and echidnas) showing that the gene entered the mammalian evolutionary pathway after the divergence from monotremes. "We think the entry of L1s into the mammalian genome was a key driver of the rapid evolution of mammals over the past 100 million years," said Adelson.

The team also looked at the transfer of BovB, a much younger jumping gene that was first discovered in cows. BovB has been shown to jump between a bizarre array of animals including reptiles, elephants and marsupials, potentially due to the action of ticks. The new research suggests that BovB has transferred at least twice between frogs and bats, possibly via bed bugs, leeches and locusts.

The team now hopes to study other jumping genes in animals such as insects and marine worms. "Even though our recent work involved the analysis of genomes from over 750 species, we have only begun to scratch the surface of horizontal gene transfer," said Adelson. "There are many more species to investigate and other types of jumping genes."





ROBOTS

DEEP LEARNING ROBOTS COULD HELP TREAT KIDS WITH AUTISM

Children with autism spectrum conditions often have trouble identifying the emotional states of people around them, struggling to distinguish a happy face from a sad one, for example. Now, researchers from MIT have designed a method based on deep learning to help teach autistic children how to read emotions more effectively using data unique to each individual child.

The researchers used SoftBank Robotics NAO, a humanoid robot that's nearly 60cm tall. NAO can convey different emotions by changing the colour of its eyes, the motion of its limbs, and the tone of its voice. The robot interacted with 35 children aged from 3 to 13, gauging their responses to displays of several different emotions such as happiness, anger and fear.

While doing this, the team captured video of each child's facial expressions, head and body movements and gestures, and recorded data on their heart rates and body temperatures. They then fed this data into a deep learning system that analysed the children's behaviour and engagement.

They found that the deep learning system agreed with the analyses of five human experts 60 per cent of the time. Typically human experts are in agreement around 50 per cent of the time.

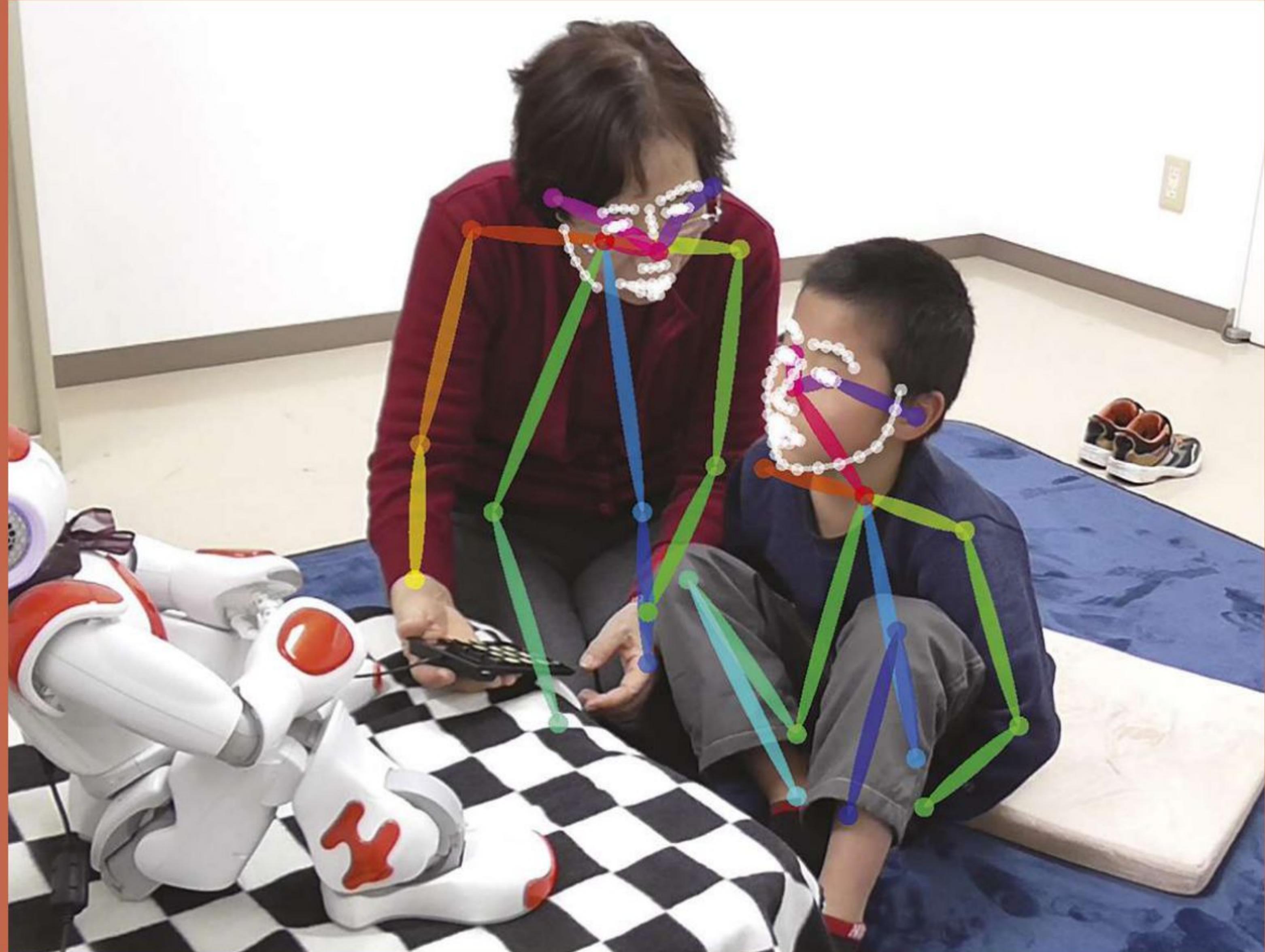
"The long-term goal is not to create robots that will replace human therapists, but to augment them with key information that the therapists can use to personalise the therapy content and also make more engaging and naturalistic interactions between the robots and children with autism," said study leader Dr Oggi Rudovic.

To find out how tech is providing insight into children with autism, turn to p74.

What is deep learning?

Deep learning is the name for computer programs that simulate networks of neurons like those in our own brains. They're hugely simplified and don't really work in quite the same way that real neurons work, but nevertheless, they enable computers to learn.

RIGHT: In the MIT study, data on each child's facial expressions and movements were gathered while they interacted with the NAO robot



ZOOLOGY

SECRET TO PARROTS' INTELLIGENCE FOUND

Who's a pretty and clever boy, then? Neuroscientists at the University of Alberta have identified the neural circuit they believe is behind the unusual intelligence seen in some parrots. The discovery is an example of convergent evolution – where organisms not closely related evolve similar traits – between the brains of birds and primates, and could potentially provide insight into the neural basis of human intelligence, they say.

Using brain samples from 98 birds, including everything from chickens and waterfowl to parrots and owls, the scientists studied an area of the brain known as the medial spiriform nucleus (SpM). They found that parrots have an SpM that is much larger than that of other birds, possibly explaining their unusual levels of intelligence.

In birds, the SpM is responsible for transferring information between the two largest areas of the brain, the cortex and cerebellum, which allows for higher-order processing and more sophisticated behaviour.

In humans and other primates, the pontine nuclei performs this same function.

"The SpM is very large in parrots. It's actually two to five times larger in parrots than in other birds, like chickens," said Dr Cristian Gutierrez-Ibanez, who co-authored the research. "Independently, parrots have evolved an enlarged area that connects the cortex and the cerebellum, similar to primates. This is another fascinating example of convergence between parrots and primates. It starts with sophisticated behaviours, like tool use and self-awareness, and can also be seen in the brain. The more we look at the brains, the more similarities we see."

Next, the research team hopes to study the SpM in parrots more closely, to understand what types of information go there and why.

"This could present an excellent way to study how the similar, pontine-based process occurs in humans," said Gutierrez-Ibanez. "It might give us a way to better understand how our human brains work."

Who're you calling bird-brained?





SPACE

MARS IS ENGULFED IN A GLOBAL DUST STORM

Next time you find yourself complaining about the weather, take comfort in the fact that you are not living on Mars. NASA's Curiosity rover has taken a snap of a thickening dust storm as it gathers on the surface of the Red Planet.

The storm has been gathering momentum for weeks and is now officially a 'planet encircling' event, researchers say. It has grown so thick that the Opportunity rover, which runs on solar power, is no longer able to operate. As Curiosity is powered by a nuclear battery, it has not been affected.

The last storm of global magnitude that enveloped Mars occurred in 2007, five years before Curiosity landed there.

Curiosity, along with a fleet of spacecraft orbiting Mars, will allow scientists to collect a wealth of information about the dust both

from the surface and from space for the first time, the researchers say.

Martian dust storms are relatively common, especially in the planet's southern hemisphere during spring and summer, when the planet is closest to the Sun. As the atmosphere warms, winds generated by large differences in surface temperatures at different locations stir fine dust particles into the air. Furthermore, carbon dioxide released from melting polar caps is released. This thickens the atmosphere and helps to suspend the dust particles in the air.

Dust storms also occur on Earth in desert regions such as North Africa, the Middle East and the southwestern United States, but factors such as stronger gravity and the effects of plants binding soil together prevent them from spreading globally.

IN NUMBERS

15

The number of galaxies the Milky Way has devoured since its formation 13.51 billion years ago.

\$14 TRILLION

The annual cost of damage caused by worldwide flooding due to climate change by 2100, as estimated by the Institute of Physics.

98

The number of people needed to maintain a healthy population on a trip to Proxima Centauri b, the nearest Earth-like exoplanet, as calculated by a team at the University of Strasbourg.

THEY DID WHAT?!

AI TRAINED TO ARGUE WITH HUMANS

What did they do?

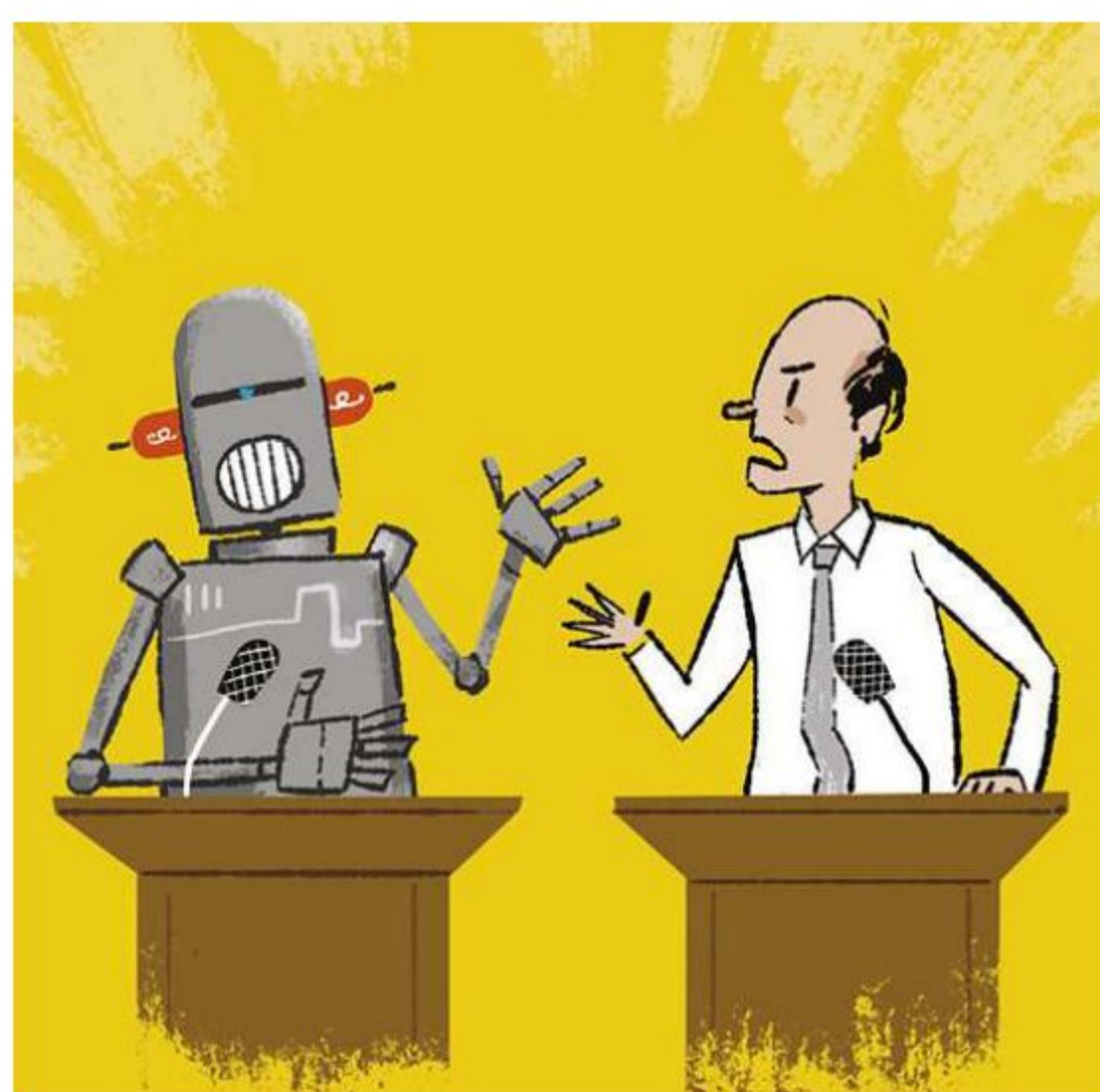
IBM developed an artificial intelligence system called Project Debater to take part in a series of public debates with two human champions. All three contestants delivered brief speeches on the topics 'we should subsidise space exploration' and 'we should increase the use of telemedicine' followed by brief rebuttals on the points made by the other contestants. The audience then voted on who made the more convincing argument.

What did they find?

Project Debater was able to form coherent arguments, deliver them with few grammatical errors and respond to points raised by the human debaters. Though the humans scored more highly in terms of delivery, the AI scored better in facts and research, and even changed some of the audience's views on the subjects.

Why did they do that?

The project was intended as a demonstration of the ability of AI to contribute to decision-making. Such systems could be used to help people reason by providing compelling, evidence-based arguments and limiting the influence of emotion, bias or ambiguity.



ESO X2, JAN STEJSKAL, ILLUSTRATION: ADAM GALE

ASTRONOMY

BIRTH OF PLANET CAUGHT ON CAMERA

What a shot! Astronomers at the Max Planck Institute for Astronomy have caught the first confirmed image of a new planet forming around a young dwarf star.

Dubbed PDS 70b, the infant planet has coalesced in the primordial disc of gas and dust orbiting the dwarf star PDS 70, which lies approximately 370 light-years from Earth in the constellation Centaurus.

"These discs around young stars are the birthplaces of planets, but so far only a handful of observations have detected hints of baby planets in them," said Dr Miriam Keppler, who led the team that spotted the planet. "The problem was that, until now, most of these planet candidates could just have been features in the disc."

The planet was spotted with the SPHERE planet-hunting instrument on the European Southern Observatory's Very Large Telescope. By using a coronagraph to block out the light of the star, the astronomers were able to pick out PDS 70b orbiting its parent star at a distance of approximately three billion kilometres – roughly equivalent to the distance between the Sun and Uranus.

Analysis of the observations found PDS 70b to be a gas giant with a mass a few times that of Jupiter and a surface temperature estimated to be 1,000°C – hotter than any of the planets in our Solar System.

"Keppler's results give us a new window onto the complex and poorly understood early stages of planetary evolution," said Dr André Müller, whose team is investigating the young planet. "We needed to observe a planet in a young star's disc to really understand the processes behind planet formation."

Müller's team of researchers are testing theoretical models of planet formation against the atmospheric and physical characteristics observed on PDS 70b.

MAIN IMAGE: Wide-field image of sky around dwarf star PDS 70 (marked with arrow)

INSET: PDS 70b can be seen forming around its parent star, whose light has been blocked with a coronagraph

CONSERVATION

IN VITRO FERTILISATION COULD SAVE NORTHERN WHITE RHINOS FROM EXTINCTION



Fatu (pictured) and her mother Najin are the only northern white rhinos left

New hope for the survival of the northern white rhino has emerged with the creation of the first in vitro, hybrid rhino embryos.

With only two females left alive, the northern white rhino is classified as being functionally extinct. But an international team of scientists has combined cryopreserved semen from northern white rhino males with egg cells harvested from southern white rhinos to produce a viable embryo.

“These are the first in vitro produced rhinoceros embryos ever. They have a very high chance of establishing a pregnancy once implanted into a surrogate mother,” said Prof Thomas Hildebrandt of the Leibniz Institute for Zoo and Wildlife Research in Berlin.

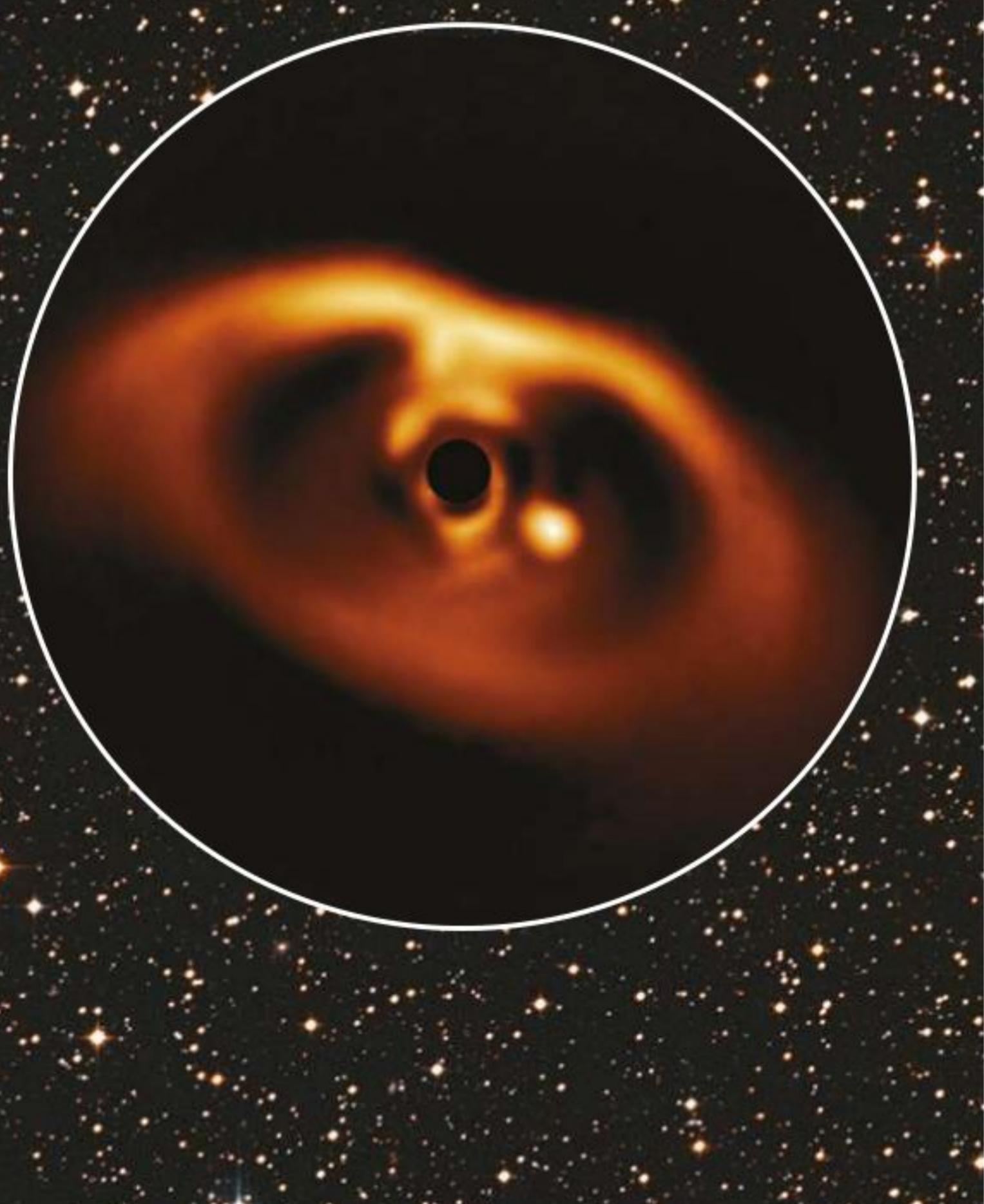
The team adapted a technique used for assisted cattle and horse reproduction to harvest oocytes (immature egg cells) from captive southern white rhino females. Harvesting oocytes from rhinos is tricky because their ovaries can’t be reached by hand and lie next to a

major artery that could cause a fatal bleed if punctured. To get around this the team developed a two-metre-long, ultrasound guided device to safely extract the oocytes.

The extracted oocytes were then combined with northern white rhino sperm and cultured until a blastocyst, an early form of an embryo, developed.

“Our results are solid, reproducible and very promising. Now we’re well prepared to go to Kenya and collect oocytes from the last two northern white rhino females to produce pure northern white rhino blastocysts,” said Hildebrandt.

But having only four males’ frozen sperm and two living females means subsequent generations of northern white rhinos won’t have the genetic diversity necessary to propagate the species. So the scientists are planning to use stem cell technology and northern white rhino tissue to create new reproductive cells that can be transplanted into the rhinos’ sperm and eggs.



NEUROSCIENCE

“The neurons have a completely different activity pattern before the movement”

Planned and immediate movements are processed differently by the brain. Dr Benjamin Dann of the German Primate Center explains how it might help humans

ABOVE: According to a study using macaques, planned and immediate movements have distinct patterns in the brain before the movement is initialised

What's the difference between planned movements and immediate reactions?

One example is when you're waiting for a green light, preparing to press the gas pedal of your car, but if a child runs onto the street, you have to brake. Both are the same movement of putting your foot down, but in one case you have to react as quickly as possible, in the other you have time to prepare.

How did you compare the two movements?

We used the example of grasp movement. This study was done with macaque monkeys, which are the best model for humans. We trained two monkeys to grasp a handle in front of them with either a precision grip, like when you pick up a biscuit, or a whole-hand or power grip, like when holding a tennis racquet. On a monitor, we gave a visual cue which told the monkey how to grasp. The visual cues were circles: grey for precision grip, green for power grip. There was also a red circle for telling the monkey not to grip – they were only allowed to execute the grip once the red circle had disappeared. The researchers showed those circles at various 0.1-second intervals from 0 to 1.3 seconds. In the brain, the first decision

was to choose the type of grip – power or precision – then wait for the visual cue [the red circle disappearing] to indicate the start of the movement.

And how did you measure brain activity?

We first implanted microelectrodes inside the skull. Unfortunately any non-invasive method is not suitable yet as the signal is too blurry. We were able to not just record individual neurons [brain cells], but hundreds of them – the whole network, actually – everything that's participated in the planning, as well as in control of the movement itself.

How does the brain activity differ?

The movement itself is identically coded in the relevant motor areas of the cortex [the brain's folded outer layers]. However, the population of neurons involved in this process has a completely different activity pattern before the movement is actually initialised. This distinct activity pattern within the brain, or 'state', is only present for working memory – short-term memory used while planning movements – and not when you react right away. All of a sudden this extra state appears



BELOW: A macaque brain is the best match for a human brain (below), which is why these monkeys were used in the study



DIGESTED READ

Movements are identically coded by motor areas in the brain's cortex (red), but the neurons involved have a different pattern depending on if the movements are planned or immediate. This different pattern is reached if the brain has had half a second of preparation time.

when the minimum preparation time, the reaction time, is half a second.

Could identifying two brain states help in medicine?

This is basic research and we never know for sure if this will actually lead to a clinical application. It is a long-term goal. This could potentially be used for rehab of patients after stroke or tumour surgery: we can say, "We know that these two states have to exist in a healthy subject, now they're both present again, the patient has re-learned the proper ability." Or even a step further, knowing the configuration for a certain state and the errors involved, to try and reactivate that by artificial electric stimulation. Another potential application is prosthetics and how to control a robot limb by brain activity. Knowing that movement is a distinct state helps a lot because you want the arm to only move when the patient wants it to move.



MARRIED COUPLES

Keele University carried out a meta-analysis of studies and found that married couples have a lower risk of heart disease and stroke than single, divorced or widowed people. The effect may be due to the enhanced wellbeing of having a partner.

THE YOUNG AT HEART

People who feel younger than their age show fewer signs of brain ageing in MRI scans, researchers at Seoul National University have found. This could be due to those who feel younger leading more physically and mentally active lives, they say.

GOOD MONTH

BAD MONTH

MILLENNIALS

Millennials have another thing to worry about: they are likely to have worse health in middle age than their parents. The Health Foundation found that the stress, anxiety and lower quality of life faced by millennials is likely to lead to a higher risk of cancer, diabetes and heart disease later in life.

HELICOPTER PARENTS

Children raised by controlling parents have poorer control over their emotions and worse social skills than those raised in a more relaxed manner, a team at the University of Minnesota has found. Kids used to doing things for themselves are better at adjusting to the changing demands of the classroom, they say.



TRENDING

Your guide to the hottest topics in the world right now

#PLASTIC

PAPER STRAWS AHOY!

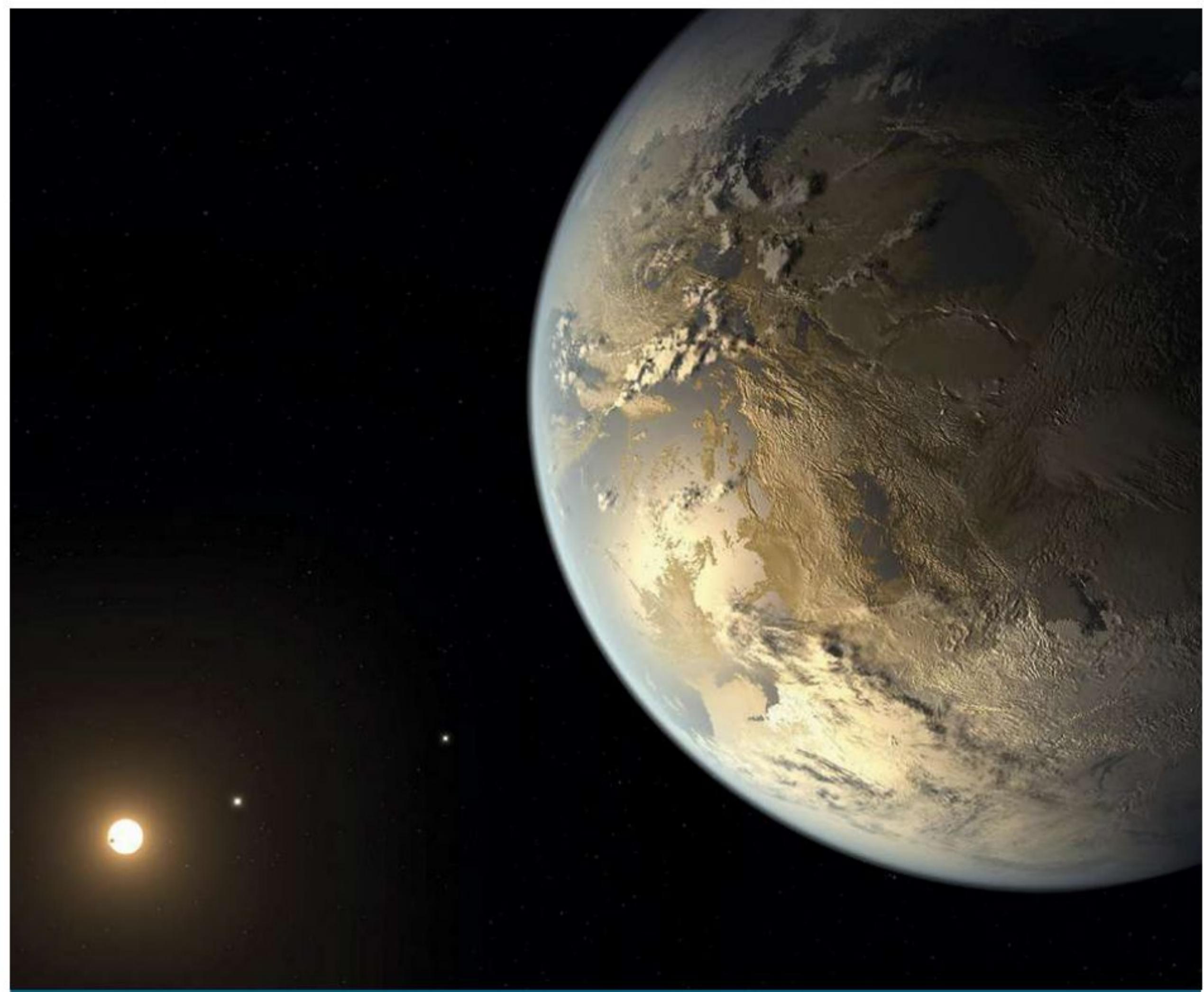
A dedicated paper straw production line is to open in Ebbw Vale, Wales, ahead of the ban on several single-use plastic products that's expected to come into force next year. It will be the first factory of its kind for several decades.

PLASTIC FROM PLANTS

Biodegradable plastic made from lignin, a natural glue found in plant stems, may be available in the next five years. Researchers at the University of Warwick have developed a method of treating lignin with a bacteria called *Rhodococcus jostii* to produce a durable biodegradable plastic.

PAPER BAGS FOR PRODUCE

Morrisons supermarket is reintroducing brown paper bags for loose fruit and vegetable purchases as part of a move it says will save around 150 million small plastic bags from being used every year. The bags will be made from 100 per cent recyclable paper and will be available in all of the supermarket chain's 493 stores by the end of summer.



#EXOPLANETS

EARTH-LIKE EXOPLANETS

Two Earth-like exoplanets, Kepler 62f and 186f, may have regularly occurring seasons and stable climates, researchers at the Georgia Institute of Technology have found. Computer simulations run by the team have predicted that the two planets both have a stable axial tilt like the Earth, meaning that they have regular seasons and stable climates, and could potentially hold onto an atmosphere.

LIFE ON MOONS

Astronomers from the University of California have found more than 100 giant planets that potentially host moons capable of supporting life. The planets were found in data collected by NASA's Kepler telescope. At more than three times the radii of the Earth, these gaseous planets are less common than rocky terrestrial planets, but each is expected to host several large moons. Scientists speculate that exomoons might provide a favourable environment for life – perhaps even better than conditions on Earth – because they receive energy not only from their star, but also from radiation reflected by their planet.

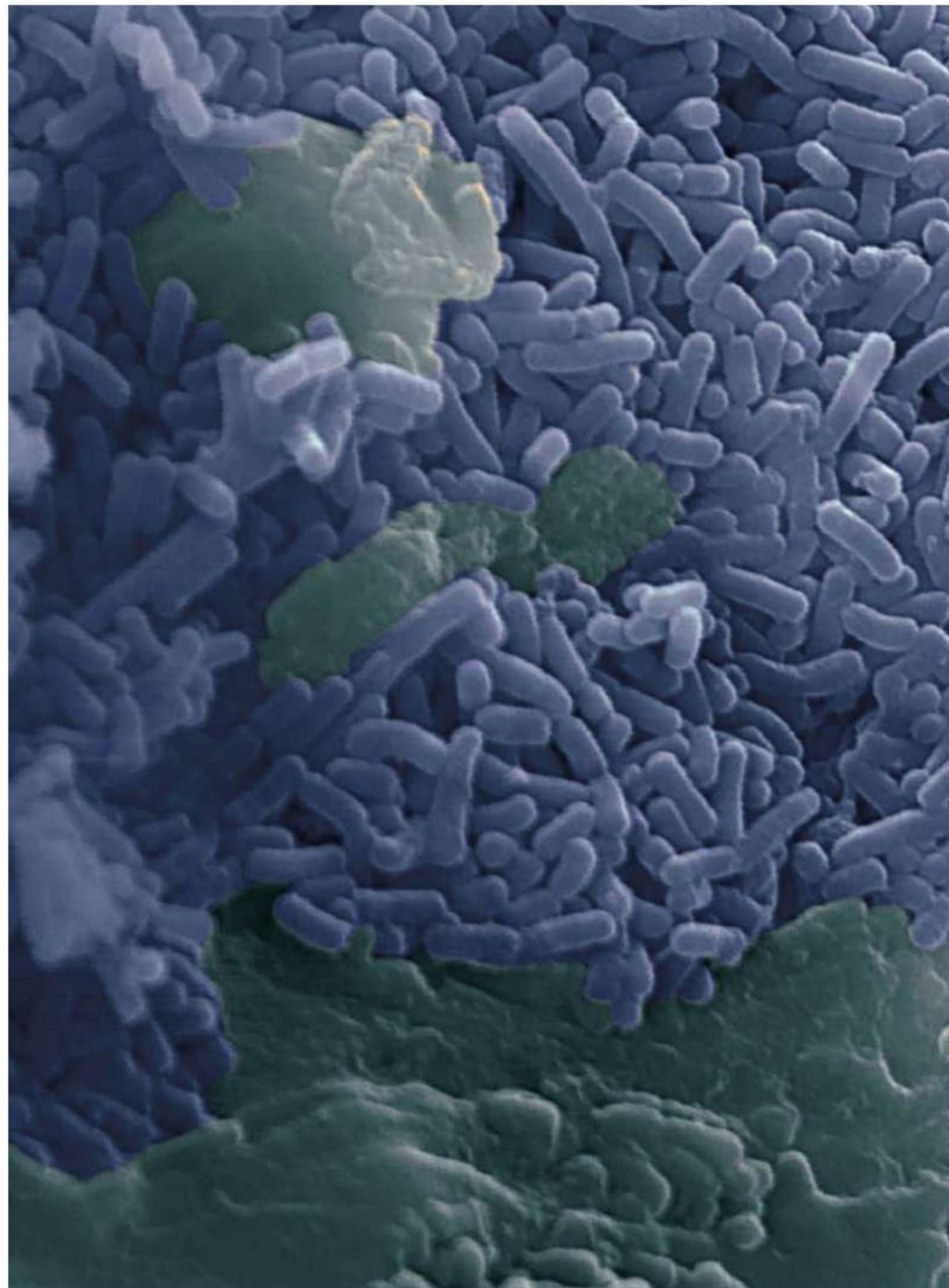
#CLIMATE CHANGE

BYE BYE, BABY

Rising temperatures due to climate change are leading to a decline in birth rates, a team at UCLA has found. After trawling through 80 years' of US birth rate data looking for trends, they found that periods of hot weather seemed to have a negative impact on the number of children born nine months later. It is thought that the effect is due to sperm production falling as temperatures soar.

BREAKING THE ICE

A 6.4km-long iceberg has been filmed breaking away from a glacier in eastern Greenland. Researchers from New York University captured the event during a trip in June. Melting ice is a concern – if the entire Western Antarctic Ice Sheet were to melt, it would result in a three-metre sea level rise, which is enough to cause serious flooding in many coastal areas.



#MENTAL HEALTH

MOOD-BOOSTING BACTERIA

Beneficial bacteria injections can kick-start anti-inflammatory effects in the brain, making it more resistant to the harmful effects of stress. Researchers at the University of Colorado have found that injecting rats with *Mycobacterium vaccae* boosted the levels of the anti-inflammatory protein interleukin-4 in the hippocampus – a brain region responsible for modulating cognitive function, anxiety and fear. The rats who received the injections were much less anxious when placed in stressful situations, they say. The researchers are now working on a study to investigate if a different bacterial strain, *Lactobacillus reuteri*, can help returning war veterans to cope with the effects of post-traumatic stress disorder.

NATURE 1, DEPRESSION 0

Taking a walk in nature may help to reduce the risk of suffering depression, according to researchers at Stanford University. The team had two groups of volunteers walk for 90 minutes, one in a grassland area scattered with oak trees and shrubs, the other alongside a traffic-heavy four-lane road. The researchers found little difference in physiological conditions between the groups, but marked changes in the brain. Neural activity in the subgenual prefrontal cortex, a brain region active during repetitive thought focused on negative emotions, was markedly decreased in the people who enjoyed the grassland walk compared to those who strolled along the busy road.

MEDICINE

CANNABIS OIL

WHAT IS IT AND CAN IT REALLY BE MADE INTO MEDICINE?

The government is reviewing the legal status of cannabis products as parents of children with severe and hard-to-treat epilepsy say it's the only thing that helps control their kids' daily seizures.

Recently, 12-year-old Billy Caldwell (pictured) made headlines when UK Customs officers confiscated seven bottles of cannabis oil from his mother, Charlotte Caldwell, who had flown to Canada to bring the product back.

Billy and his parents were eventually allowed to take the oil back to their home in Northern Ireland, but only after being granted a special temporary Home Office licence. Other parents of children with severe epilepsy – who may experience hundreds of seizures a day – say that they're being forced to break the law and obtain products of dubious quality in their attempts to obtain medicinal cannabis.



What is 'medicinal cannabis'?

The cannabis plant contains many different compounds called cannabinoids. The two most significant ones are tetrahydrocannabinol (THC) and cannabidiol (CBD). While THC is the compound that gets recreational cannabis users high, CBD is of great interest to researchers for its medical properties. On its own, CBD has shown promise in the treatment of many health problems, including multiple sclerosis, epilepsy, anxiety, Alzheimer's, schizophrenia, pain and Tourette's.

Only one CBD-based drug is licensed for use in the UK. This is Sativex, used for the treatment of multiple sclerosis. It contains CBD and THC and has undergone stringent safety testing and clinical trials. Epidiolex, a highly-purified form of CBD used to treat epilepsy, has been approved in the US but is still awaiting approval for use in the EU.

With cannabis-based drugs for epilepsy and other disorders such as anxiety not yet available in the UK, people are seeking out unregulated cannabis oils and other products from online suppliers or abroad.

What is cannabis oil?

Cannabis oil is a general term for any liquid extract that's made from cannabis or hemp plants. Dr David Potter, a cannabis expert involved in both the production of medical-grade CBD and the analysis of illicit cannabis, says these products can vary hugely in terms of how they're made and what they contain. "Some of the oils we've analysed are quite close to what they say they contain, others are way off," he says. The oils are often marketed as food additives to avoid having to adhere to the strict quality standards required of medicines.

How does CBD work?

CBD is just 1 of over 100 compounds known as cannabinoids that are found in the cannabis plant.

These substances act on our 'endocannabinoid system', a complex part of the nervous system that helps regulate a variety of processes – including our sleep cycle, appetite, pain sensation, mood and memory.

Cannabinoids like CBD and THC bind to receptors in this system throughout the body and brain, sometimes activating them and sometimes suppressing or blocking them.

The exact reason CBD appears to be so useful in treating various disorders is unclear. It does not have the intoxicating effects of THC, and intriguingly seems to have almost the exact opposite effect to high doses of THC.

Research shows that CBD has appetite-suppressing properties, unlike the famous cannabis-induced 'munchies', and it has anti-anxiety and anti-psychotic properties as opposed to the paranoia and psychosis induced by high-doses of THC. It is these properties that have led to people purchasing CBD oil to try to alleviate problems such as insomnia and anxiety.

Is cannabis oil legal in the UK?

According to the Home Office, any material that contains THC is a Schedule 1 drug, meaning it's classed as having no therapeutic value and is illegal. Despite breeders developing plants with high CBD levels and low THC levels, it's impossible to breed a cannabis plant that contains no THC at all. Therefore, many cannabis oils are likely to contain small amounts of THC as well as CBD. According to the Home Office, any material that contains more than 0.05 per cent THC is a Schedule 1 drug, meaning it's classed as having no therapeutic value and is illegal. Currently in the UK there is one brand of CBD oil that contains less than 0.05 per cent THC and is now available in high street shops such as Holland & Barrett.

What about the rest of the world?

Similar debates about medicinal cannabis are playing out all around the world. In Canada, high-strength CBD-based products are legal to buy in shops; Canada was where Billy Caldwell's mother obtained the high-strength cannabis oil confiscated in the UK – she's also the director of a cannabis oil company out there. However, in other countries, all cannabis products remain completely illegal.

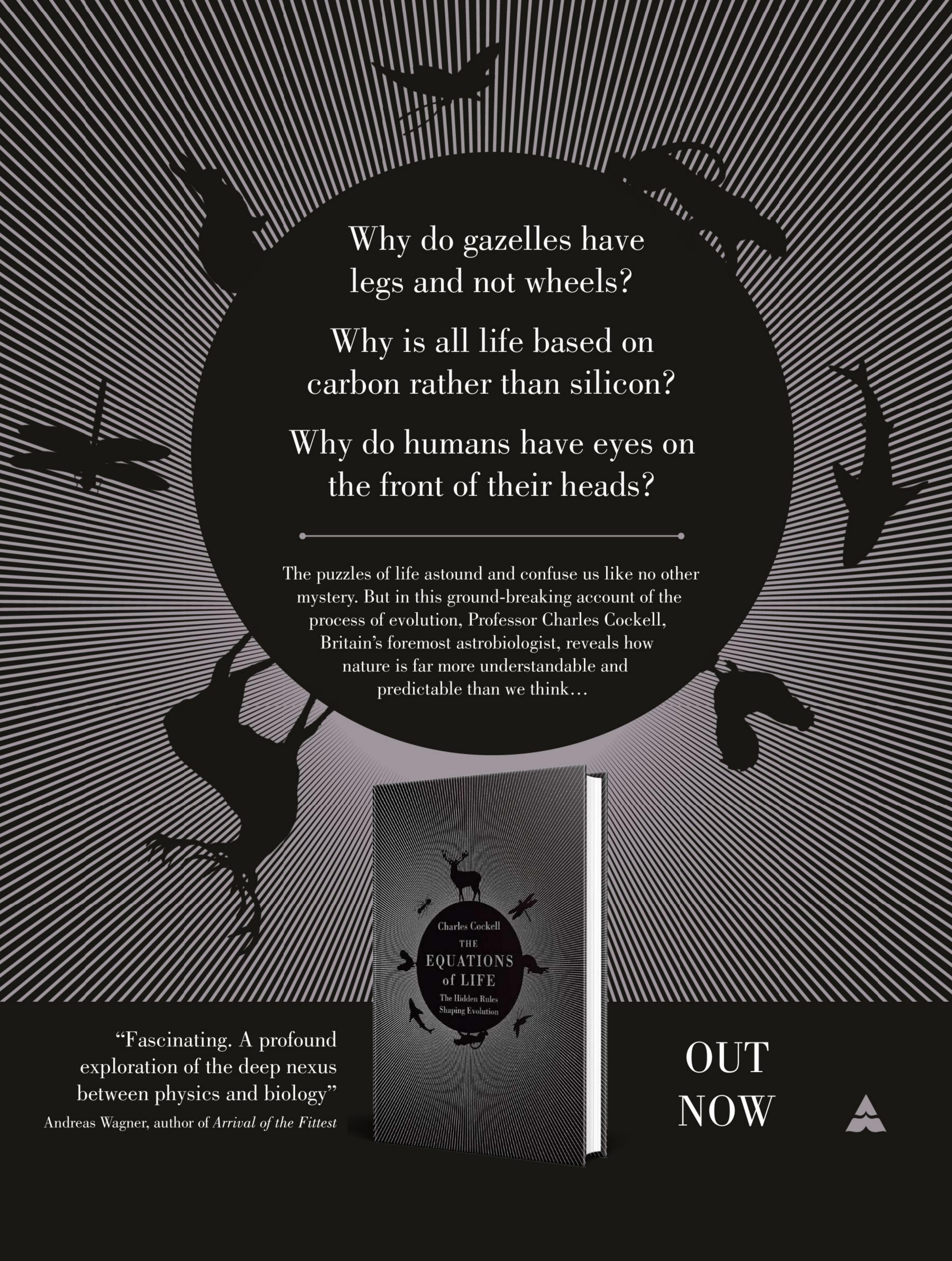
Will cannabis be made legal in the UK soon?

In June, England's chief medical officer Dame Sally Davies published a report concluding that there was now evidence of 'therapeutic benefit' from some CBD-based cannabis products. After further pressure from campaign groups, UK home secretary Sajid Javid has ordered a review into whether accessing cannabis for medicinal use should be made easier.

Following this review, cannabis products may be reclassified as a Schedule 2 drug, meaning recreational cannabis use would still be illegal, but it would be easier for cannabis-related products to be studied and prescribed.

Billy Caldwell's case has sparked a review of policy concerning medicinal cannabis oils



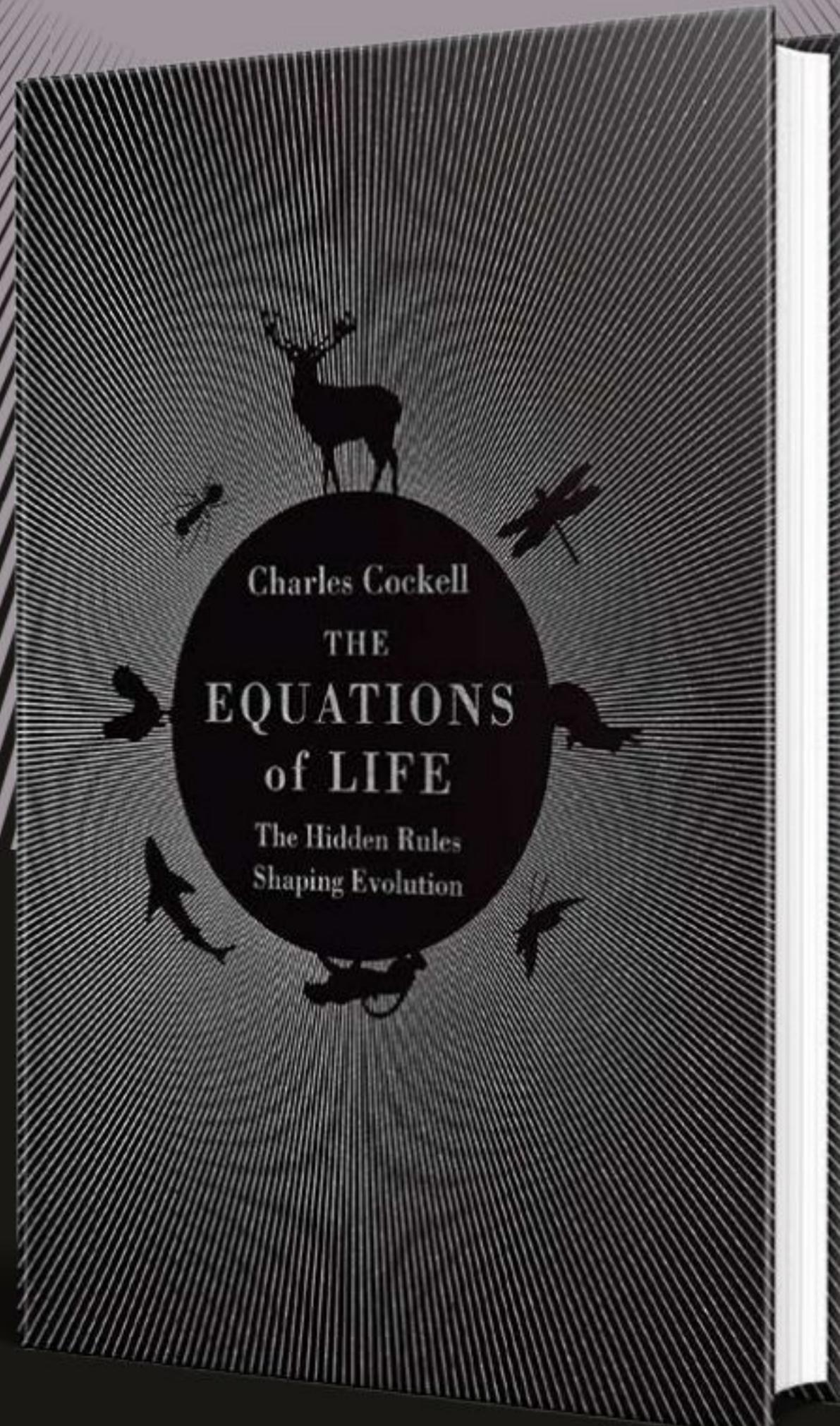


Why do gazelles have
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Why is all life based on
carbon rather than silicon?

Why do humans have eyes on
the front of their heads?

The puzzles of life astound and confuse us like no other mystery. But in this ground-breaking account of the process of evolution, Professor Charles Cockell, Britain's foremost astrobiologist, reveals how nature is far more understandable and predictable than we think...



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OUT
NOW



"HOW A PAIR OF MAVERICK SCIENTISTS CHANGED MANY LIVES"



DR MICHAEL MOSLEY

BBC
TWO

Michael is a science writer and broadcaster, who presents *Trust Me, I'm A Doctor* on BBC Two. His latest book is *The Clever Guts Diet* (£8.99, Short Books).

Recently, I returned from a trip to Perth, Western Australia, where I met one of my medical heroes, Prof Barry Marshall. Not only did his research improve the lives of millions of people, it also changed my life, in a strange and unpredictable way. And it turns out that there is a new and unexpected twist to his work.

Back in 1993, I was a pushy assistant producer working in the BBC science series department. I was desperate to make a programme for *Horizon* and was fishing around for ideas to pitch.

I came across an article about two Perth-based researchers, Barry Marshall and Robin Warren, who were making some extraordinary claims about stomach ulcers – painful sores in the stomach lining. Back then, ulcers were common and considered incurable, and the standard advice if you had one was to eat bland food, change your stressful lifestyle and take a drug to reduce acid production. If that didn't work, and it often didn't, you might find yourself having parts of your stomach and small bowel removed. But Barry and Robin were arguing that most ulcers are not caused

by stress, as was commonly believed, but were the result of infection by a previously unknown bacterium that they had identified and named *Helicobacter pylori*.

To make his point, Barry swallowed a flask of *H. pylori* bacteria. A few days later, he started vomiting. He had himself endoscoped and samples of his now inflamed stomach lining were removed. These showed that his stomach had been colonised by *H. pylori*. After 10 days, he took antibiotics, which he had shown could kill the bacteria, and was soon back to normal.

He did that experiment in 1984 and despite the fact that he and Robin, and many others, demonstrated the effectiveness of this approach, most of the experts I interviewed for my 1994 film, *Ulcer Wars*, still dismissed Barry's work out of hand. One of the experts said he refused to believe a major breakthrough could have come out of an "academic backwater like Perth".

So I was delighted, 10 years after my film went out, when Barry and Robin

It is thought that up to two-thirds of the world's population are infected with *H. pylori*, but it doesn't cause symptoms in everyone.

won the Nobel Prize for Medicine for their work. It is now standard practice to look for *H. pylori* infection when people have stomach ulcers.

Inspired by Barry's example, I decided to pitch to the BBC a series on the history of medicine, told through the stories of self-experimenters. It took me 13 years to get *Medical Mavericks* commissioned, by which point I was no longer behind the camera but in front of it. My style of presenting involves a high degree of self-experimenting.

The twist to this particular story, which I promised at the beginning of this article, is that having spent the last couple of decades trying to eradicate *H. pylori*, Barry and his team are now trying to reintroduce it into people's lives. They've discovered that it is a powerful suppressor of the immune system and could be used to treat allergic diseases, such as eczema and asthma, in young children. They have carried out research in animals and have shown that a safe form of *H. pylori* can indeed reduce signs and symptoms of allergic disease. Watch this space. 





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INNOVATIONS

PREPARE YOURSELF FOR TOMORROW

AUGUST 2018

EDITED BY HELEN GLENNY

H₂WOAH!

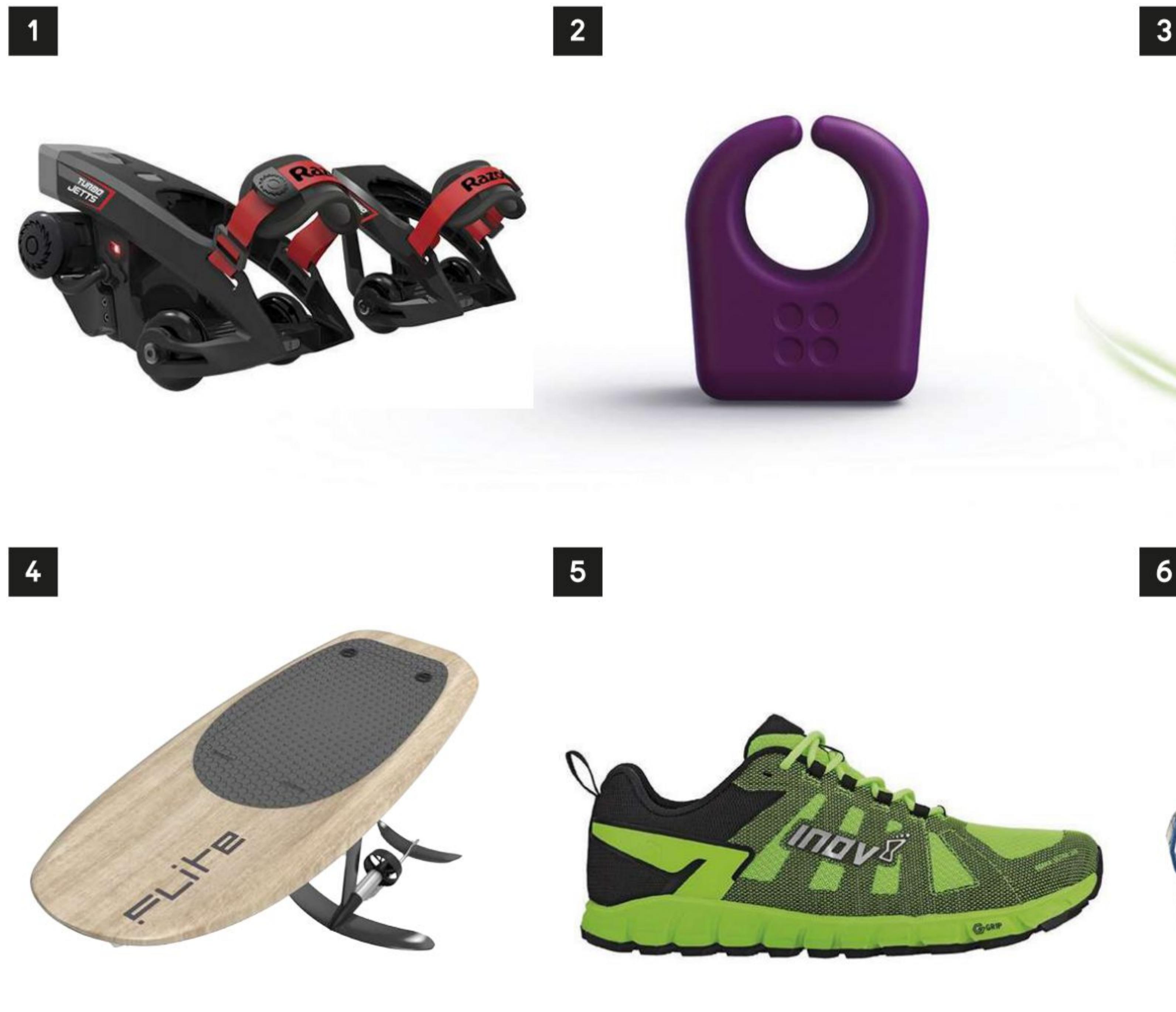
Toyota Motor Europe is sponsoring the Energy Observer, the first hydrogen-powered ship, on a six-year voyage around the world. It's the first autonomous hydrogen vessel that emits no greenhouse gases or fine particles, powered by a combination of renewable energies and a system that produces carbon-free hydrogen from seawater.

The ship's primary sources of power are its 130 square metres of solar panels and two wind turbines. It creates hydrogen by removing salt and ions from seawater, before separating out the oxygen and

hydrogen through electrolysis. The hydrogen is then stored in tanks to be used when needed, providing a buffer against the intermittent supply of solar and wind at sea. Hydrogen is a light and efficient fuel, so it can be easily stored onboard.

The Energy Observer is 30.5 metres long and has a potential top speed of 42 knots, although it usually cruises between 8 and 10 knots. It was launched in Saint Malo in April 2017, and over the next six years it will call in at 101 ports in 50 countries, including Tokyo for the 2020 Olympic Games.





WANTED

1 FREE WHEELERS

These electric heel wheels clamp on to your shoes and power your joyrides around the local park. They have a 12V lithium-ion battery, and a top cruising speed of 16km/h (10mph). Just don't come crying to us if you fall.

Razor Turbo Jetts
£129.99, razor.com

2 DRUMMING ON

Put some Specdrums rings on your digits and connect to the app. Start tapping colours and assign sounds to them. Then you can use Specdrum rings to play whatever's around you: your clothes, drawings, or even the contents of your fruit bowl.

Specdrums
ETBC.specdrums.com

3 SAFETY FIRST

Mount these lights on your bike and you'll have turn indicators, brake lights, front lights and flashing rear lights. The Blinkers are hooked up to a remote on your handlebars, so they're easy to use while riding.

Blinkers
From £79.99 (ETBC), blinkers.bike
Blinkers.bike

4 FLYING ON WATER

This wooden board lets you glide above the water, powered by an underwater propulsion system. You can cruise at up to 40km/h (25mph), with no need for wind or waves – all you need is metre-deep water and even deeper pockets.

Fliteboard
£8,995 (approx £8,000), fliteboard.com

5 TOUGH AS OLD BOOTS

Inov-8 have infused graphene, a super-strong, lightweight material, into the rubber soles of their TerraUltra G 260 trail-running shoes, while the uppers contain Kevlar. It'll take a few thousand laps around the block to wear these out...

TerraUltra G 260
£140, inov-8.com

6 BRACING FOR IMPACT

This phone, designed by Philip Frenzel, a student from Germany's Aalen University, could be a saviour for clumsy folk. It shoots out shock-absorbing legs when sensors detect the phone is in freefall, protecting it from impact. It's just a prototype for now, but fingers crossed it gets picked up for development.

SUBSCRIBE AND RIDE

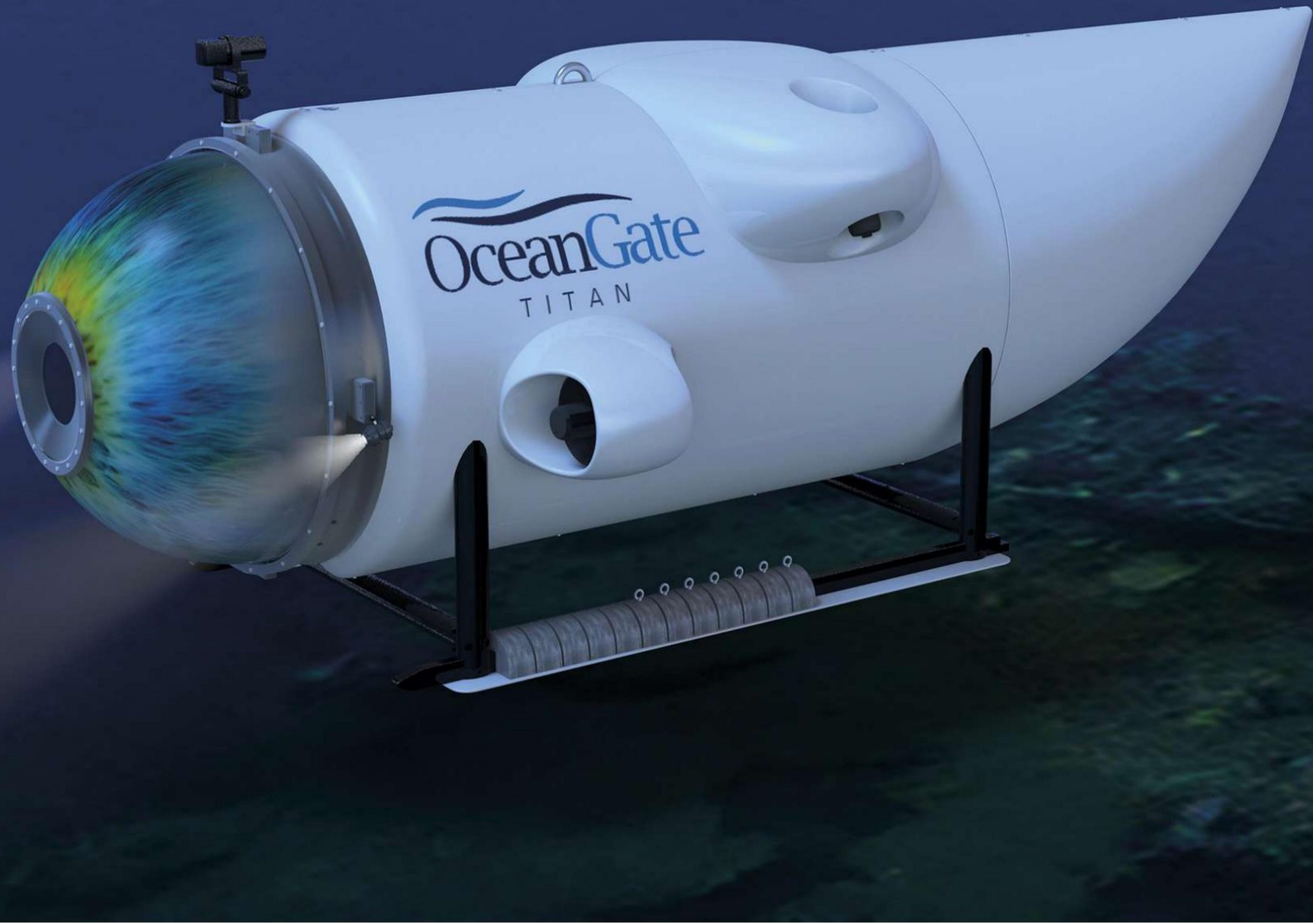
Dutch bike company VanMoof has already left tracks on the bicycle business, with a world-first subscription service and alarmingly advanced anti-theft protection. Now, it's adding two new electric bikes to its range. The Electrified S2 and X2 both have an intelligent motor, pedal assist and quick-charge mode. They can travel 150km (93 miles) on a single charge, which is enough to cruise from London to Brighton and back.

They also come with a 'stealth lock' system. If a bike is tampered with, it emits loud warning sounds, deterring potential thieves. If it's stolen, the bike enters lockdown mode, where all systems are shut down and the lights flash. If that doesn't deter the pesky thief and they make off with the bike, the owner can alert VanMoof's Bike Hunters and they'll track it down. If they can't recover the bike within two weeks, they'll replace it.

If you'd rather not invest the full £2,298, VanMoof runs a subscription service where you pay a 'key fee' when you first receive the bike, and a monthly fee while you're using it.

VanMoof Electrified S2 and X2
£2,398, vanmoof.com





EXPLORATION

DIVE THE TITANIC

OceanGate is offering people the chance to explore the *RMS Titanic*, 3,800 metres below the surface of the Atlantic Ocean, starting in 2019. No manned expeditions have visited the wreck in 15 years.

They're not purely sightseeing missions. Since the ship sank in 1912, she's been subject to microorganisms munching away at the ship's steel structure, and no accurate estimates have been made about how long the shipwreck will be recognisable. The crew on OceanGate's missions will collaborate with scientific experts to assess the decay of the site, collecting 4K images and video, scanning the wreck and the debris field, and collecting laser and sonar data. This will all be done from aboard the Titan, a small submersible that

can fit up to six people (a passenger, four crew and a sub pilot). During the 90-minute descent, passengers will be able to look for bioluminescent creatures, help the pilot monitor the inertial navigation system and pick up views of the ship via sonar.

During three hours exploring the wreck, the team will check out the ship's deck, investigate the area where the ship's famous grand staircase was located, and take a look at the ship's enormous debris field, where numerous artefacts have sat for over a century.

OceanGate's taking bookings already. A ticket costs \$105,129 per person (approx £80,000), which OceanGate claims is the cost of the first-class ticket on the ship's original 1912 sailing, adjusted for inflation.

OceanGate's deep-sea submersible will take keen explorers to the *RMS Titanic*... all you need is £80,000 and a complete lack of claustrophobia

ROBOTS

DISNEY'S STUNT ROBOTS STICK THE LANDING

Disney's new autonomous stunt robots can flip through the air like expert trapeze performers, making on-the-go corrections and hitting the nets perfectly every time.

Earlier this year, Disney researchers created Stickman, a long, thin robot capable of tucking up into a Z-shape for a smooth backflip. They've been improving Stickman at a rapid pace and have now debuted Stuntronics, which is their next-generation somersaulting robot.

The 41kg figure uses onboard accelerometers and gyroscopes, supported by laser range finding

to help spot landings. It makes its own real time decisions, all while performing stunts up to 18 metres in the air. After being flung from the end of a wire, it can tuck its knees to somersault, pull its arms in to twist, and extend its legs to slow down to make perfect landings.

Disney's mission is to create realistic robot figures that can perform complex acrobatic stunts at Disney's theme parks. Although the exterior doesn't look like a superhero yet, the robot's human-like movements are enough to fool you at first glance.



This still from Disney's footage shows the Stuntronics robot performing elaborate acrobatics

OCEANGATE INC., WALT DISNEY IMAGINEERING RESEARCH & DEVELOPMENT

TECH BYTES



UV BOTS

A new hospital sanitation robot can eliminate virtually all organisms in just 10 minutes, using the power of ultraviolet light. The iPT 3200 decreased healthcare-associated infections by 34 per cent in a six-month rollout in a hospital.

SPEED-WRITING

Chinese online commerce giant Alibaba has debuted a new AI copywriting tool. It uses deep learning and language processing to learn from millions of existing samples to write product descriptions. It's passed the Turing test and can produce 20,000 lines of copy per second.

GOODBYE, MAPS

Mercedes has a new augmented reality satellite navigation system that films the area around you and overlays easy-to-follow arrows pointing exactly where you need to go. Say goodbye to confusing bird's-eye map layouts.



ON TEST: MID-RANGE MASTERS

Yes, our smartphones are pretty darn good at photography these days, but ambitious amateurs might fancy something a bit more serious. DANIEL BENNETT gets snapping...

If you're wild on wildlife, mad on motorsports or yearn to make it big on YouTube, then there's never been a better time to upgrade to a camera that's a bit more serious than a smartphone. There are two routes for budding 'prosumers'. One is traditional DSLRs: big cameras with big lenses and big batteries.

The other is smaller, mirrorless cameras – sometimes called compact system cameras – which still allow for interchangeable lenses, but are built for those of us who want something a little more discreet. We test out two of the best options in each category, to find out which we'd go for.





CANON 80D

The 80D is a multitasking maestro. Its smart DualPixel Autofocus makes life easy. Whether you're trying to snap the kids bombing into the pool, or attempting to film yourself talking to camera, the 80D just seems to read your mind and homes in on your subject. It's what, I presume, makes it so popular with YouTubers hoping to make videos on the fly. Similarly, the autofocus marries well with the camera's video features, automatically focusing on faces and letting you shift focus using touchscreen controls. The fully articulating display helps too, pivoting so you can shoot from interesting angles, or just see yourself while you talk to camera.

It's no slouch on images either. With a bit of practice, fast-moving objects – like a car screaming down a racetrack or a bird taking flight – are easy to keep pin-sharp, while the fast focus means you can get in more shots in quick succession. The 24-megapixel sensor also provides images big enough to let you shoot first and crop later. Meanwhile, the dynamic range – its ability to pick up differences in light and colour – is also brilliant, picking up nuances in greys and blacks well in landscapes and in lowlight settings, though perhaps not in as impressive a manner as the newer Nikon. The only thing missing from this camera is the ability to shoot 4K video. A second SD slot would have been nice, and really seasoned photographers might want the ability to move the focus to the very edges of the image.

£1,029.90, canon.com

Picture quality 8

Performance 10

Features and build 8

Value 9

Overall 9

NIKON D7500

The D7500 nails picture quality. Although there's not a lot between the two DSLRs, the Nikon's output looked cleaner and more detailed than the Canon's. Indoors on a bright day, the camera captured the subtleties of dappled light and soft shadows, despite the overall brightness of the setting. Outside, pointed at the cloudy Mendips, the camera managed the best job of capturing the nuances of the rolling hills and undulating shadows.

The D7500's autofocus feels slower than the 80D, doubly so if you try to shoot video. In fact, if you want to record a lot, then you might want to look elsewhere. But if you do stick to the camera's viewfinder, the autofocus works brilliantly once it's locked on to its target. The camera's 3D tracking shifts the lens's focus as your subject moves through the frame, making it perfect for a spot of bird-watching. It's particularly good in lowlight situations where other cameras might struggle.

While shooting through the viewfinder, the electronic display presents all of your camera settings. It's all so neatly set out that we ended up using the touchscreen more than the physical buttons for once. Unfortunately, the screen isn't fully articulated like the Canon's. The Nikon can film in 4K, though it shrinks the frame in order to save the film to the memory card, which is a slight issue if you're a fan of the wide-angle shots you get from something like a GoPro.

£1,379, nikon.com

Picture quality 9

Performance 9

Features and build 8

Value 9

Overall 9





COMPACT
SYSTEM
CAMERAS

SONY A7R II

Big quality from a small package, that's what the A7R II is all about. It actually boasts the highest resolution image sensor of the lot at 42.4MP, with a huge ISO range of 100-25,600 (a measure of how sensitive the sensor is to light). There's also some deft image stabilisation inside that eliminates the natural shakiness of your hands, allowing you take crisp images at yawning shutter speeds (we managed 1/20). The result of all this nifty tech is the best quality images of the group, but it's double the price of the others. The A7R II seems to pick up every scrap of detail, no matter what the quality of light, and produces photos that can be blown up to almost any size. These features – particularly the stabilisation – make for brilliant, smooth 4K video with plenty of dynamic range available if you want to edit the footage later. It's a particularly tempting package for budding film makers and bloggers who want to travel light without scrimping on quality.

There are some sacrifices though. Compared to DSLRs, Sony's traditional menu system feels a little contrived. There's no room for an integrated flash and all this tech stunts its battery life to 300 shots. Still, you can charge the battery via the camera's micro-USB port, which is handy if you've got a portable battery pack. The camera's features also mean it's a little on the slow side in terms of autofocus and burst photography, managing just five shots per

second. If there's a trade-off between speed and quality, Sony has prioritised the fidelity of single shots over action performance.

£2,400, sony.com

Picture quality 10

Performance 8

Features and build 9

Value 8

Overall 9



FUJIFILM X-PRO 2

On looks alone the X-Pro 2 is easily our favourite. The retro yet minimal design plucks our nostalgic heartstrings. Veteran photographers will feel instantly at home with the layout – shutter speed at the top, aperture control on the lens. The idea is that you can adjust your exposure on the fly, which we like, but this might leave others missing touchscreen controls. In a similar vein, there's a tiny joystick to the left of the screen that lets you manually position the camera's focus. The whole ethos of the camera's design is to give control to the photographer, and in the process teach you a thing or two about photography.

That said, there's still a lot of helpful tech lurking inside. The viewfinder can switch between optical and electronic modes, overlaying information about the image across the eyepiece. It can also help out when the optical viewfinder lets you down, for example, with longer, larger lenses attached or when taking a close-up pic. I was sceptical at first, but came to love it by the end of my time with the camera. The image quality was brilliant in every scenario. Fujifilm uses a less traditional system to create each pixel, but the end result feels lifelike and nuanced. There's also an ARCOS monochrome mode for authentic black-and-white photos straight from the camera. The overall quality perhaps wasn't as 'wow' as the Sony's, but then the X-Pro 2 is half the price. That said, with the Fujifilm's snappy, continuous autofocus it certainly felt a lot faster to use from the hip. The battery life is also a bit of a letdown, but again on the flipside, it offers dual SD card slots for snap-happy photographers.

£1,399, fujifilm.com

Picture quality 8

Performance 10

Features and build 10

Value 9

Overall 10

VERDICT

Ultimately, these are four brilliant cameras that'll reward aspiring photographers who invest in them. That said, since we have to pick between them, there are clearly four cameras for four different photographers.

If your priority is speed and versatility – say for shooting sports or people – there's the Canon and the Fujifilm. Both empower you to take great shots quickly. The Canon is a brilliant all-rounder, particularly for someone who wants to dabble in video, while the Fujifilm is aimed at the more seasoned photographer who wants something lightweight



to slip into a jacket pocket.

The Nikon and the Sony are both a little slower to use when the moment strikes, but offer better image quality overall. The Nikon is perfect for those on holiday wanting to flex their photography muscles on some exotic landscapes and wildlife, while the Sony offers jaw-dropping image quality, if you have the funds to spare.

If we had to choose, we'd might be tempted by the charms of the Fujifilm X-Pro 2, but we'd be equally happy with any of the above.



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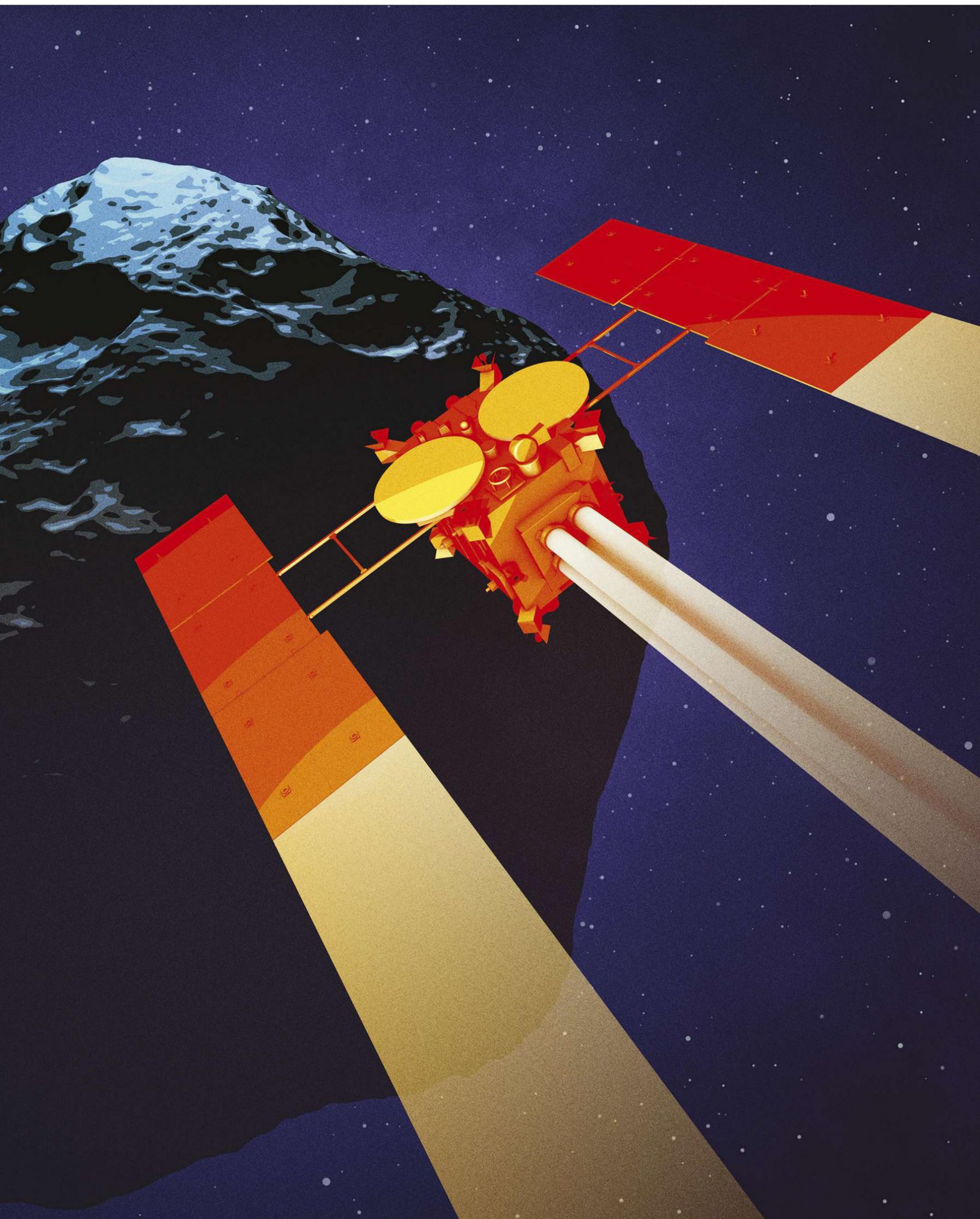
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HUNTING FOR LIFE'S COSMIC ORIGIN

TWO PIONEERING SPACECRAFT ARE ABOUT TO ENTER
ORBIT AROUND TWO DIFFERENT ASTEROIDS. WHAT THEY
FIND COULD SHED LIGHT ON HOW LIFE ON EARTH BEGAN

WORDS: PROF LEWIS DARTNELL

USIRIS-REx. Hayabusa2. Make a note of these two names: you're going to be hearing a lot about them over the coming months and years. These spacecraft – one operated by NASA and the other by the Japan Aerospace Exploration Agency, JAXA – will this summer each enter into orbit around a target asteroid. They promise to teach us a great deal about the origins of the Solar System, how we might deflect an asteroid on a collision course with the Earth, and even the molecular origins of earthly life.

Both NASA's OSIRIS-REx and JAXA's Hayabusa2 are sample-return missions, which means that not only will they touch gently onto their asteroid's surface to collect a scoop of its ancient material, but they will then return it safely back to eagerly waiting scientists on Earth. This sort of return trip mission within deep space is fabulously complex, and both probes are marvels of engineering. The Japanese probe is a follow-up to their earlier asteroid mission, Hayabusa, which returned a small sample from the asteroid Itokawa in 2010. Despite suffering numerous glitches, Hayabusa racked up a string of accomplishments, including being the first spacecraft designed to land and take off from an asteroid



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ABOVE: OSIRIS-REx being assembled prior to its launch back in 2016

RIGHT: Timeline of the OSIRIS-REx and Hayabusa2 missions

and the first to return an asteroid sample to Earth. Hayabusa2 uses the same basic spacecraft structure as its predecessor, but incorporates more backup systems to improve reliability, along with some technological advances. As well as upgrades to the communication antenna and guidance systems, Hayabusa2's ion engines are 25 per cent more powerful than its predecessor's, and the probe will be able to autonomously control its own final descent to the remote asteroid's surface. Hayabusa2 is also like a mothership in its own right – it will deploy a small lander and three rovers onto the asteroid's surface for a closer look, which can hop around the landscape to different locations.

Meanwhile, NASA's OSIRIS-Rex (Origins, Spectral Interpretation, Resource Identification, Security, Regolith Explorer) will be the first ever US asteroid sample-return mission. This spacecraft is about twice the size of Hayabusa2, and rather than using ion engines will fire standard rocket thrusters to accelerate on its trajectory to its target asteroid. When they arrive this summer, both missions will survey their target asteroids for about a year and a half, mapping the surfaces and remotely detecting minerals using spectroscopy. Scientists will then use these results to help them decide the best spot on their asteroids for Hayabusa2 and OSIRIS-REx to descend to collect their samples.

TIME CAPSULES

Asteroids are important because they represent primordial material left over from the making of the planets. They are like time capsules from before the creation of the Earth, preserving matter since the beginning of the Solar System. By studying them up-close, scientists hope to be able to answer some pretty fundamental questions about the formation and development of the Solar System. Specifically, it will help us to understand



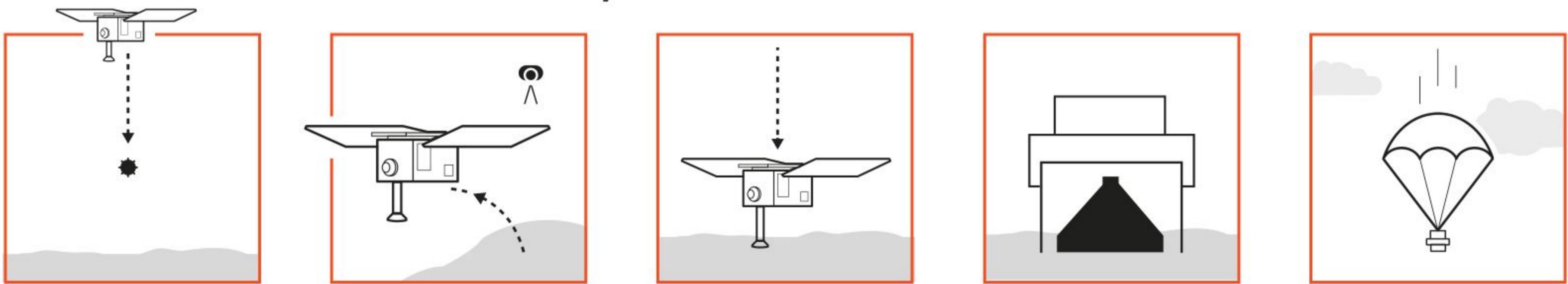
“THESE KIND OF SPACE ROCKS ARE THOUGHT TO HAVE DELIVERED A LOT OF WATER TO PRIMORDIAL EARTH”

how planets like the Earth were born, by allowing us to observe the material from which rocky planets form.

Even more excitingly, both OSIRIS-REx and Hayabusa2 are being sent to carbonaceous asteroids. These kind of space rocks have a high percentage of carbon compounds as well as water-containing minerals, and are thought to have delivered a lot of water to the primordial Earth to fill our oceans, along with organic chemicals like amino acids. As Dr Yuichi Tsuda, project manager for Hayabusa2, puts it, “The primary reason we chose our target asteroid is that it is a C-type [carbon-rich]. Telescope observations suggest that it should contain lots of carbon as well as water-related minerals, and so give us important clues as to how ➤



HOW Hayabusa2 WILL COLLECT ITS SAMPLES



1 Probe approaches asteroid Ryugu, deploying its impactor at an altitude of 500m. When detonated, this fires a 2.5kg copper projectile into the asteroid's surface, blasting out a 2m-wide crater.

2 Before detonation, the probe deploys a camera into space to watch the explosion, and escapes to the far side of the asteroid in order to protect itself.

3 When safe to do so, Hayabusa2 returns to the crater site and uses its rocket thrusters to descend, until its extendable 'sampler horn' touches the surface.

4 The sampler horn fires out a metal projectile, collecting the resulting debris in the re-entry capsule.

5 The capsule parts from its mothership on return to Earth, parachuting into the RAAF Woomera Range Complex in South Australia. Hayabusa2 moves into an orbit around the Sun.

"OSIRIS-REx IS LIKE GOING ON A GRAND FIELD TRIP, AND WHEN IT COMES BACK IT WILL BE A TRULY AMAZING MOMENT"

• life on Earth became possible. We've never explored or sampled this type of asteroid before, so these missions are really exciting".

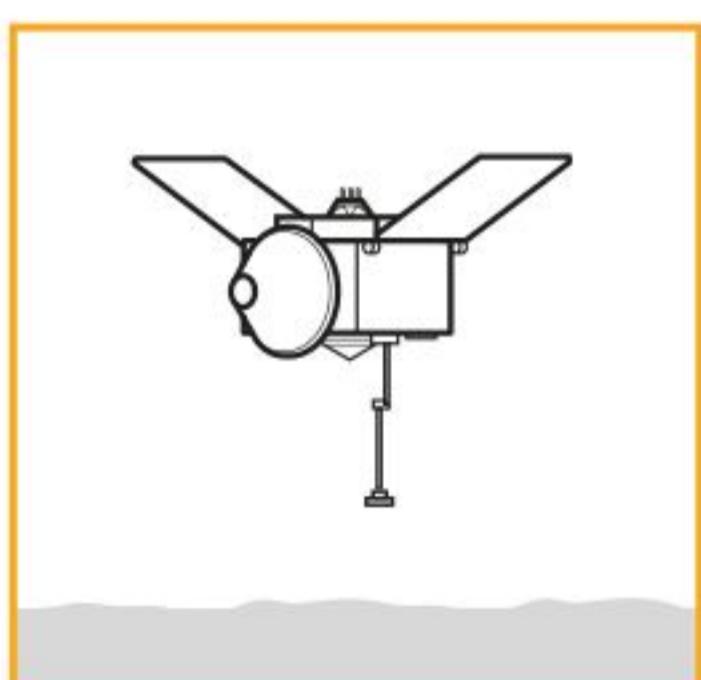
Organic chemistry forms the building blocks of all life on Earth. Cells of organisms are made up of certain molecules joined together into long chains: amino acids that build our proteins; nucleotide bases that make DNA and RNA; and the long, oily chains that make up the outer membranes of cells. We know that many of these chemical building blocks are formed in the cosmos – through what is known as 'astrochemistry' – in the cold gas clouds floating through space, as well as the warmer regions around old, dying stars. When this material pulls together under gravity as a new solar system forms, the organic molecules become incorporated into asteroids and comets. So while asteroids don't deliver fully-formed cells to young

OSIRIS-REx

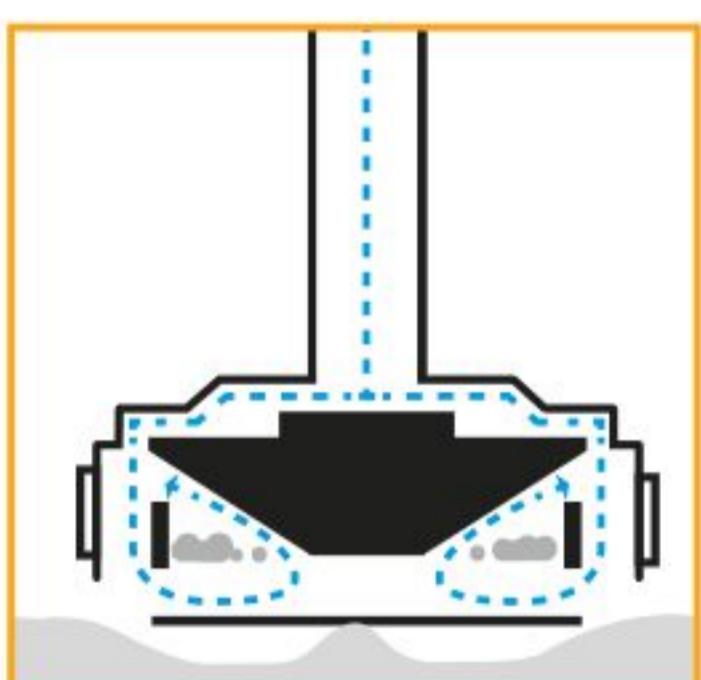
Launch mass: 2,110kg
Size: 2.43 x 2.43 x 3.15m
Target asteroid: 101955 Bennu
Launch: 8 September 2016, Cape Canaveral Air Force Station, Florida, USA
Sample size to be collected: Between 60g and 2kg
Sample return: September 2023
Power: Two solar arrays generating between 1.2kW and 3kW
Propulsion: 28 rocket engines
Fuel: Hydrazine
Estimated cost: \$800m



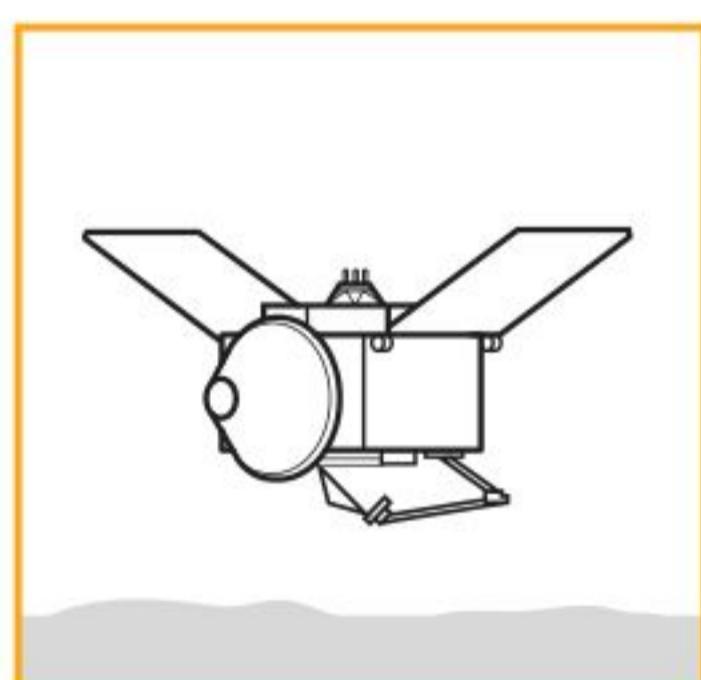
HOW OSIRIS-REx WILL COLLECT ITS SAMPLES



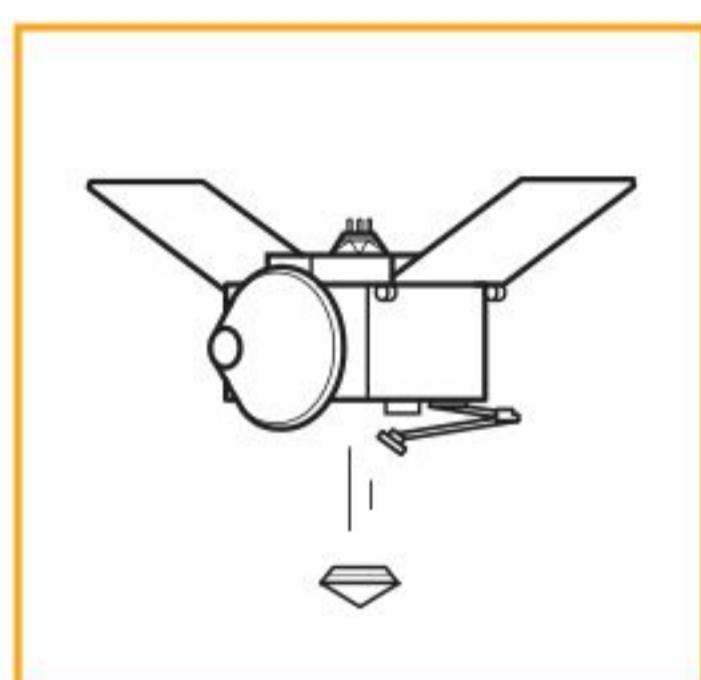
1 Probe approaches surface of asteroid Bennu, delicately positioning itself above the asteroid (without landing) using a pair of specialised low-thrust rocket engines.



2 OSIRIS-REx will touch the asteroid with its 3m-long robotic arm, using a puff of nitrogen to blow loose rock and dust into collection head at end of arm.



3 The collection head is then stowed inside the Sample Return Capsule (SRC) ready for journey home.



4 As OSIRIS-REx nears Earth, it releases the SRC, manoeuvres away and enters an orbit around the Sun.



5 The SRC parachutes into the Utah desert, complete with sample.

planets, they may have provided many building blocks for the origin of life – and finding organic molecules on these asteroids would offer support for this idea.

Organic molecules like amino acids have previously been found in meteorites that have landed on the Earth, but these missions will be the first time that scientists will be able to get their hands on carbonaceous material directly from an asteroid. Although meteorites naturally deliver us lumps of primordial space rock, as soon as they land they're susceptible to contamination from the Earth's environment. And that's why sample-return missions are so important to researchers – material

is collected from the source and hurried back via a robotic courier. Prof Sara Russell is a planetary scientist at London's Natural History Museum, and will run some of the preliminary studies on the material returned by OSIRIS-REx. "I've worked on meteorites my whole career, but we're never really sure what sort of asteroid, or where in the Solar System, they've come from," she explains. "OSIRIS-REx is like going on a grand field trip to pick our own sample, and when it comes back to Earth in 2023 it will be a truly amazing moment – a meteoriticist's dream come true!"

Both NASA and JAXA chose their target asteroids because they offer pristine carbonaceous material for researchers to study. But they also needed asteroids that are roughly the right size (with enough gravity ➤

THE NEXT GOLD RUSH?

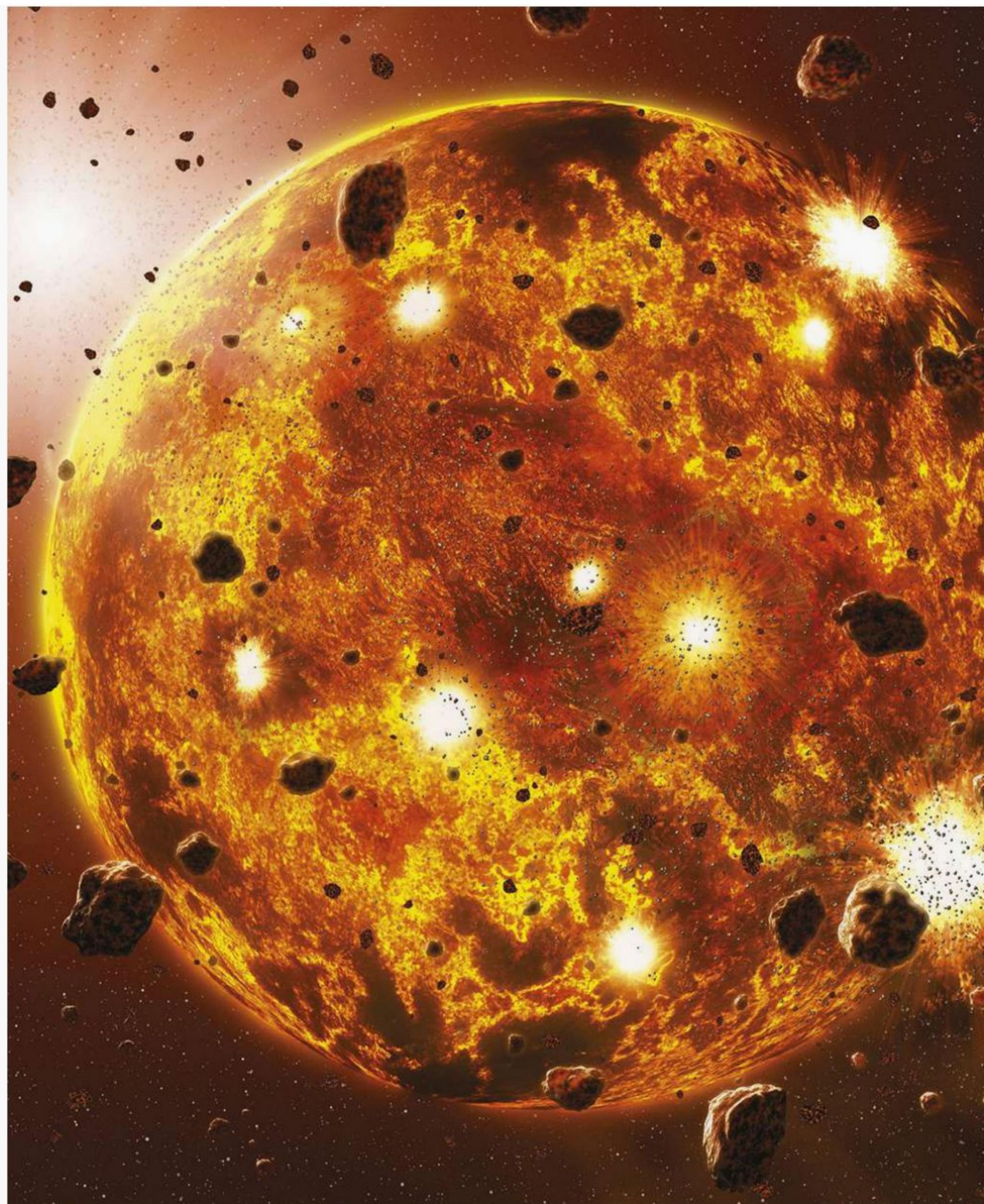
There's fabulous wealth in them thar space rocks

As well as telling us about our place in the Solar System, asteroids could also offer enormous commercial value. Several companies are already talking seriously about mining asteroids. The organic compounds and water in carbonaceous objects like Bennu and Ryugu could provide the raw materials needed for life-support systems in human exploration of the Solar System, and could even help to support long-term space colonies. Other asteroids are thought to be rich sources of precious metals.

Incredibly, a metallic asteroid a kilometre or two across could contain enough gold, platinum, tungsten and nickel to make it worth hundreds or even thousands of billions of dollars. So even considering the high costs

of space exploration, a company that can successfully extract these resources would still turn an astronomical profit.

The trick for future space mining will lie in identifying which near-Earth asteroids are economically viable to exploit, as well as how to reliably operate such deep-space missions. There are also huge uncertainties in how to mine rock in the vacuum and low-gravity of an asteroid surface. And those are just the technological challenges. There are concerns over the legal consequences of the commercial exploitation of space: the lack of adequate laws and regulation could lead to a new Wild West, with disputes over who has the right to mine which asteroids.



► for their probes to orbit), that aren't spinning too quickly (so that the probes can touch down safely), and that are in a near-Earth orbit that the probes can actually reach. "Asteroids that fit all these criteria are actually quite rare," says Prof Hitoshi Kuninaka, who has been leading the development of Hayabusa2's ion engines. The NASA scientists picked asteroid 101955 Bennu for their mission, whereas JAXA's Hayabusa2 is heading towards 162173 Ryugu. And they will collect their samples in a spectacularly audacious way.

After it manoeuvres into orbit around Bennu, OSIRIS-REx will slowly lower itself towards the asteroid's surface, without actually landing, and fold its solar panels upwards to protect them. Here, it will extend a robotic arm and puff a sharp burst of nitrogen gas to blow up particles into its collection head. After just five seconds, the sample collector will close and OSIRIS-REx will automatically begin to back away from the surface. With anything between 60g and 2kg gathered, this precious cargo will be sealed into a re-entry capsule and fired back towards the Earth, where it'll parachute safely to the ground in Utah to be picked up.

Hayabusa2 is even more innovative. It carries a device called the Small Carry-on Impactor (SCI), consisting of a 2.5kg copper projectile and a shaped charge of plastic explosive. This explosive will fire the copper impactor into Ryugu's surface at over 7,000km/h, blasting out



a crater while Hayabusa2 flies around the far side of the asteroid to protect itself from the flying shrapnel. A camera released by the probe will watch the impact, transmitting the images to Hayabusa2 before the probe returns to the crater to collect its sample. This will enable Hayabusa2 to analyse the interior structure of the asteroid, and to gather material that has not been exposed to ultraviolet radiation and the solar wind.

INCOMING!

Beyond teaching us about the origins of the Earth and the conditions for life, OSIRIS-REx and Hayabusa2 have another critical aim: to help prevent a cataclysmic cosmic collision. As Bennu and Ryugu orbit the Sun close to the Earth, they are also exactly the sort of asteroids that present a potential hazard to our planet. Asteroids have been slamming into the Earth throughout our planet's history, and the mass extinction 66 million years ago that saw the demise of the dinosaurs, along with around three-quarters of all animal and plant species, coincided with a massive impact crater in the Gulf of Mexico. Bennu and Ryugu are much smaller than the asteroid that may have triggered that extinction

LEFT: Asteroids are time capsules from the Solar System's formation

ABOVE LEFT: Recent image of target asteroid from Hayabusa2

ABOVE: Extracting samples from the first Hayabusa mission

event – they're both less than a kilometre across – but the results would still be catastrophic if they were to hit a populated area. The orbit of Bennu, for example, brings it close to the Earth every six years, and it's been calculated that there's a 1 in 1,410 chance that it might hit us between the years 2169 and 2199.

OSIRIS-REx will help us understand how the orbit of asteroids like Bennu might change over time through a process known as the Yarkovsky effect. This is a tiny force caused by the emission of infrared radiation

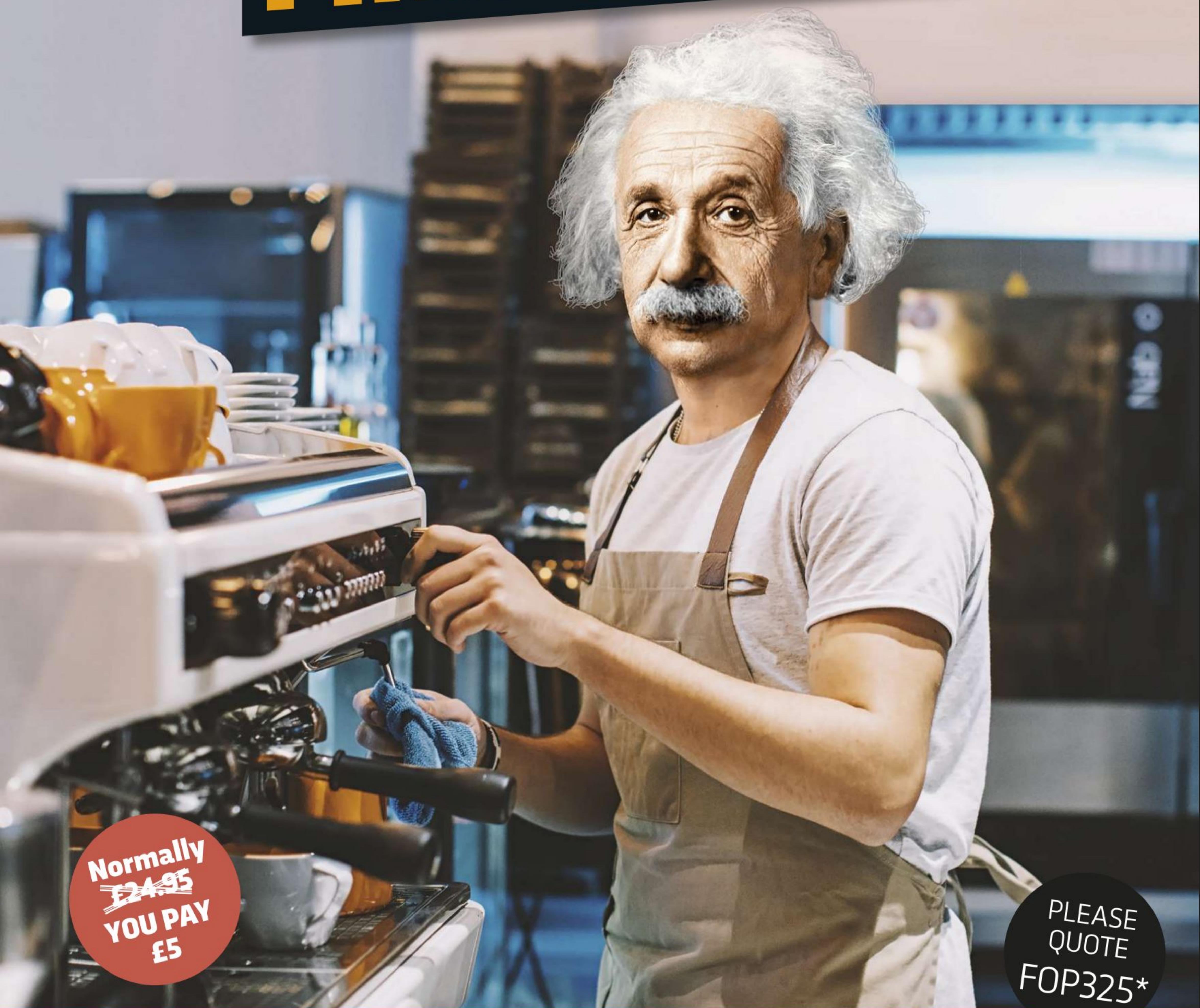
from the Sun-warmed surface of an asteroid, but over long periods it can significantly nudge an object's orbit. OSIRIS-REx will study this effect and what it means for the probability of Bennu impacting the Earth in the future. The probe will also measure the asteroid's physical properties. "It's important to understand the interior structure of asteroids like Bennu," explains Dr Kerri Donaldson Hanna, a researcher at the University of Oxford who will be helping with OSIRIS-REx's surface investigations. "Is it a single body, or perhaps composed of multiple large boulders held together only loosely? We'd need to know this before we could decide on the best technique to attempt to deflect away an asteroid if it were on a collision course."

These missions are spectacular not just for their audacity, but also for the sheer breadth of their vision. From the origins of life on our planet to protecting the life that now clings to survival here, OSIRIS-REx and Hayabusa2 promise to offer new insights into our place in the cosmos. ■

"OSIRIS-REx AND HAYABUSA2 COULD HELP PREVENT A COSMIC COLLISION"

Prof Lewis Dartnell is an astrobiology researcher at the University of Westminster. His latest book *Origins: How The Earth Made Us*, is out in January (£18.99, Bodley Head).

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SPERM - STOPPERS

THE SEARCH FOR A MALE CONTRACEPTIVE PILL

For over half a century, women have been able to take control of their bodies to prevent pregnancies. But many men now want to share this responsibility with their partners. So how long will they be waiting for a male pill?

WORDS: DR KAT ARNEY

WATCH THIS

BBC
TWO

Look out for an upcoming episode of *Horizon* all about the female and male contraceptive pills.

M

ore than 50 years ago, in 1960, the first female hormonal contraceptive pill, Enovid, was approved by the US Food and Drug Administration (FDA), with the UK following in 1961. Just five years later, millions of pills were being popped around the world every day as women took control of their reproductive choices and health, creating a seismic change in society.

Today, women have a wide range of reliable, reversible options for controlling their fertility, including intrauterine devices (IUDs), patches, jabs and implants. Men have just two: condoms, which have a 15 per cent failure rate under real-life conditions and are disliked by many couples, and vasectomy – cutting the tubes that shuttle sperm from the testes to the penis. And although vasectomy reversal is possible, it doesn't always work. So why don't we have a male pill?

The history of the male contraceptive pill has been a lot more up and down than the female pill. Its origins date back to the 1950s, when US biologist Gregory Pincus, one of the co-inventors of the female pill, found that doses of a synthetic version of the male sex hormone testosterone could switch off sperm production in the same way that the female hormones in the pill shut down ovulation. ➤

“The science behind the male pill is analogous to the female pill”

“The physiology and science behind the male hormonal contraceptive pill is analogous to the female pill,” explains Prof Stephanie Page, an expert in male reproductive biology at the University of Washington in Seattle. “Giving men an external source of testosterone blocks their own production of the hormone in organs like the testes. They still have plenty of it in their blood, so it doesn’t affect the rest of their body, but developing sperm need 100 to 1,000 times as much testosterone for their final maturation and there just isn’t enough in the testes to enable them to finish developing.”

SPERM STOPPER

At the University of Minnesota, chemistry professor Dr Gunda Georg is taking an alternative approach. She and her colleagues are investigating a chemical called ouabain – a potent toxin produced by plants, which was originally used by east African tribes to coat the tips of their hunting arrows. It exerts its effects by blocking molecules called sodium potassium ion transporters, which normally shuttle salts in and out of cells. Curiously, one

particular component – the alpha 4 subunit – is only found in transporters in sperm cells, and nowhere else in the body.

“When we removed the gene encoding the alpha 4 subunit in male mice, we found that they were quite normal in all respects except that they were infertile,” Georg says. “The animals even made normal sperm, but they couldn’t swim up the fallopian tube to get to the egg and they couldn’t do the final wriggling movement that leads to fertilisation. This suggested that if we could develop a drug that selectively blocks alpha 4, then this would be a promising approach for male contraception.”

In search of ideas, Georg and her team hit the textbooks, looking for ways to modify the chemical structure of ouabain so it would only hit alpha 4 and nothing else. Then once they’d tweaked the molecule, they tested it in rats to see if it would work. Amazingly, they hit the jackpot first time. ◉

A BRIEF HISTORY OF THE PILL



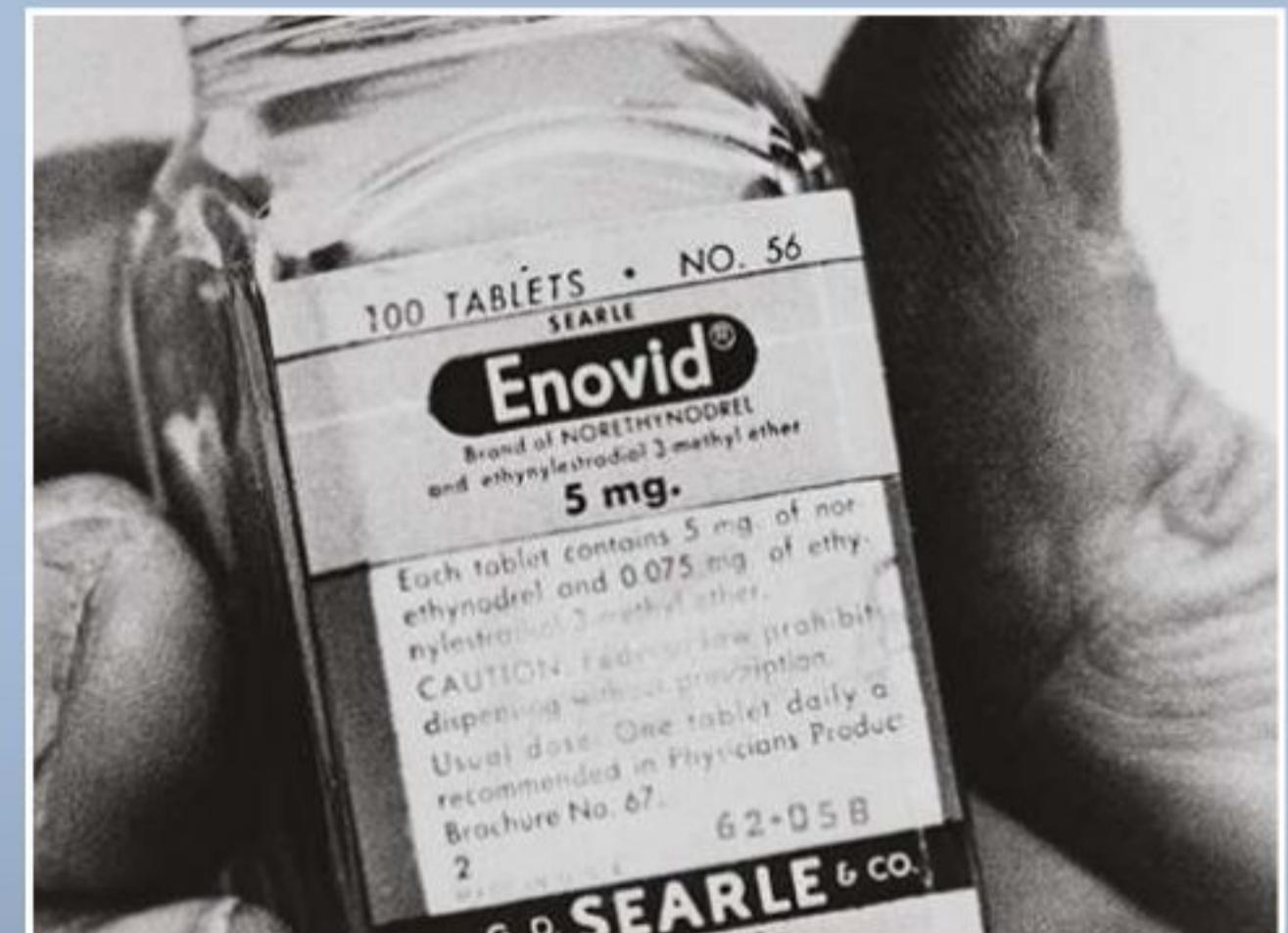
The story of the female contraceptive pill starts in the 1950s, when US researcher Dr Gregory Pincus (above left) started searching for chemicals that interfere with fertility in animals. He figured out that giving female animals doses of sex hormone progesterone would shut down ovulation, preventing eggs from being released.

Pincus teamed up with gynaecologist Dr John Rock (above middle), who was already testing chemical contraception in women, and they secured funding from women's rights activist, biologist and wealthy heiress Katherine McCormick. At the same time, Dr Carl Djerassi, a chemist working in Mexico, was working out how to create artificial hormones from inedible yams. Eventually he



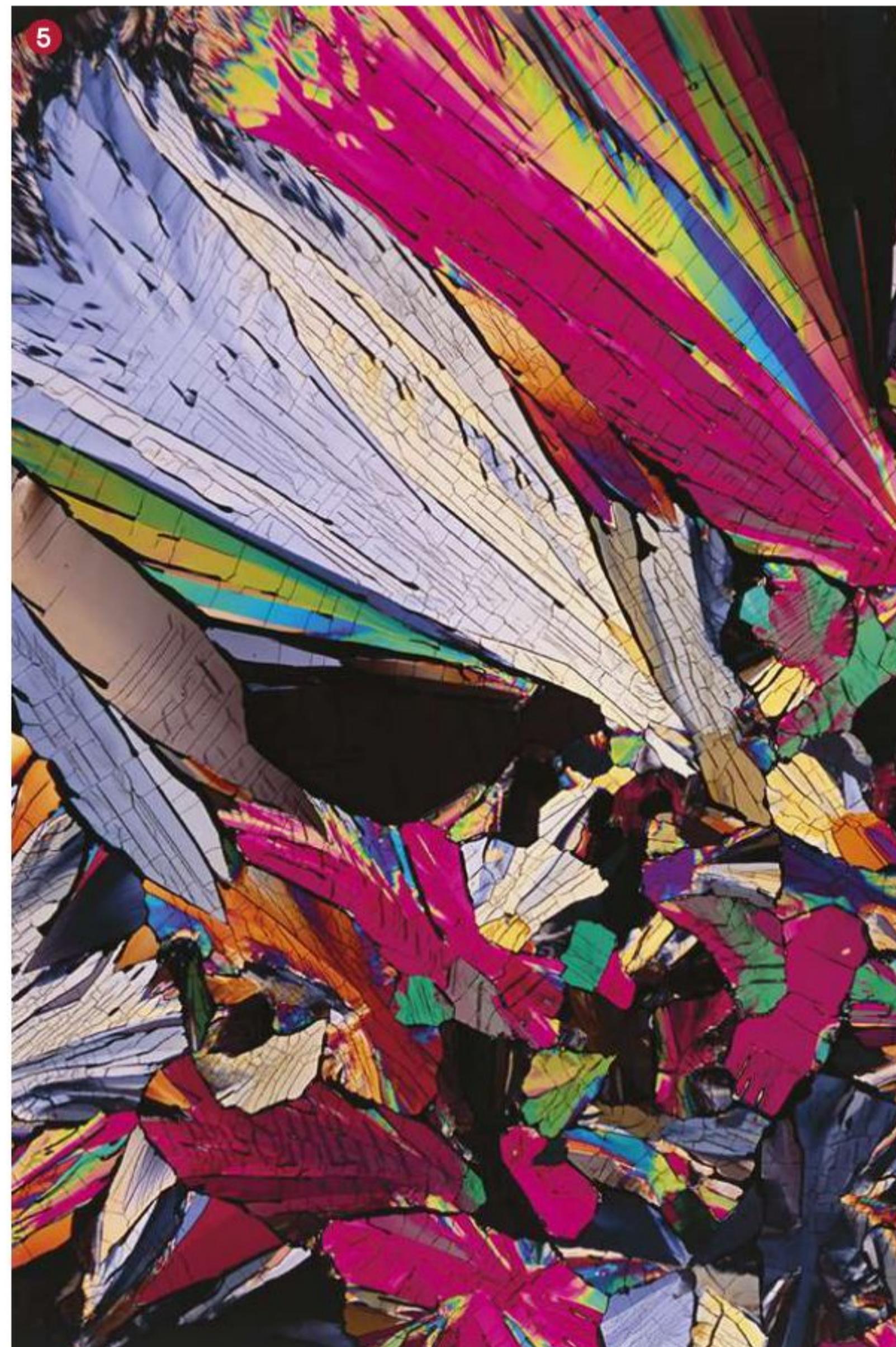
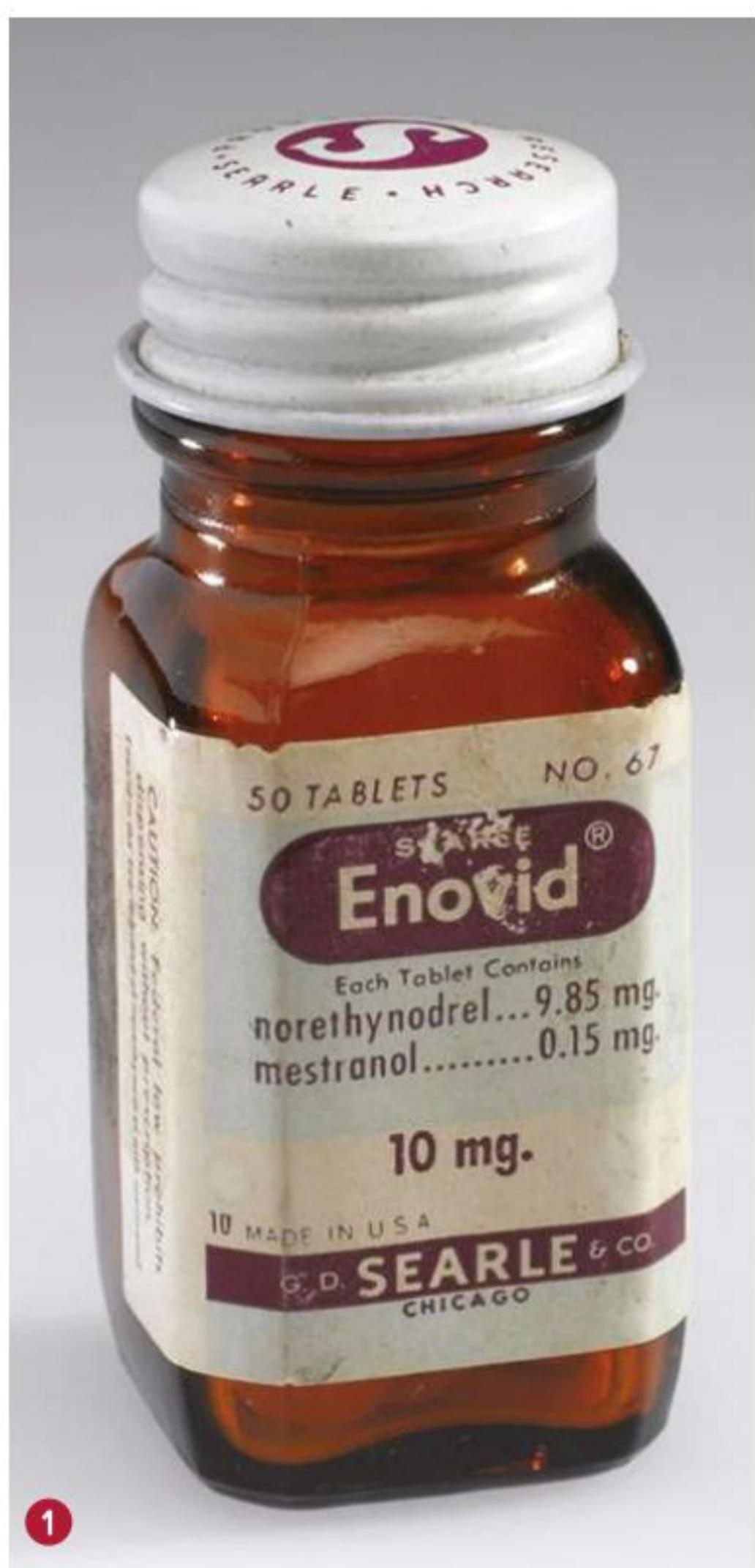
managed to make norethindrone – a synthetic version of progesterone. Enovid – a combination of artificial oestrogen and progesterone – first went into clinical trials in Massachusetts in 1954 (above right), with larger-scale studies taking place in Puerto Rico in 1956. Initially approved by the FDA for menstrual disorders, it was finally given the green light as a contraceptive in 1961.

Sales accelerated rapidly as women grabbed the chance to take control of their reproductive choices and health. Since then, millions of women all over the world have taken hormonal contraception, and there are many versions on sale. The pill is extremely effective at preventing pregnancy, with an



almost 100 per cent success rate as long as it's taken correctly, and it can also help with irregular or painful periods.

The success of the pill is tempered by growing concerns about possible side effects that may not have been flagged up by the early clinical trials. By 2010, there were more than a thousand pending lawsuits claiming that various pills could cause blood clots, heart attacks and strokes. Large studies have shown that it can increase the chance of breast and cervical cancers (although it reduces the likelihood of developing womb or ovarian tumours), and some studies have suggested that hormonal contraception can affect mental wellbeing and may even increase the risk of suicide.



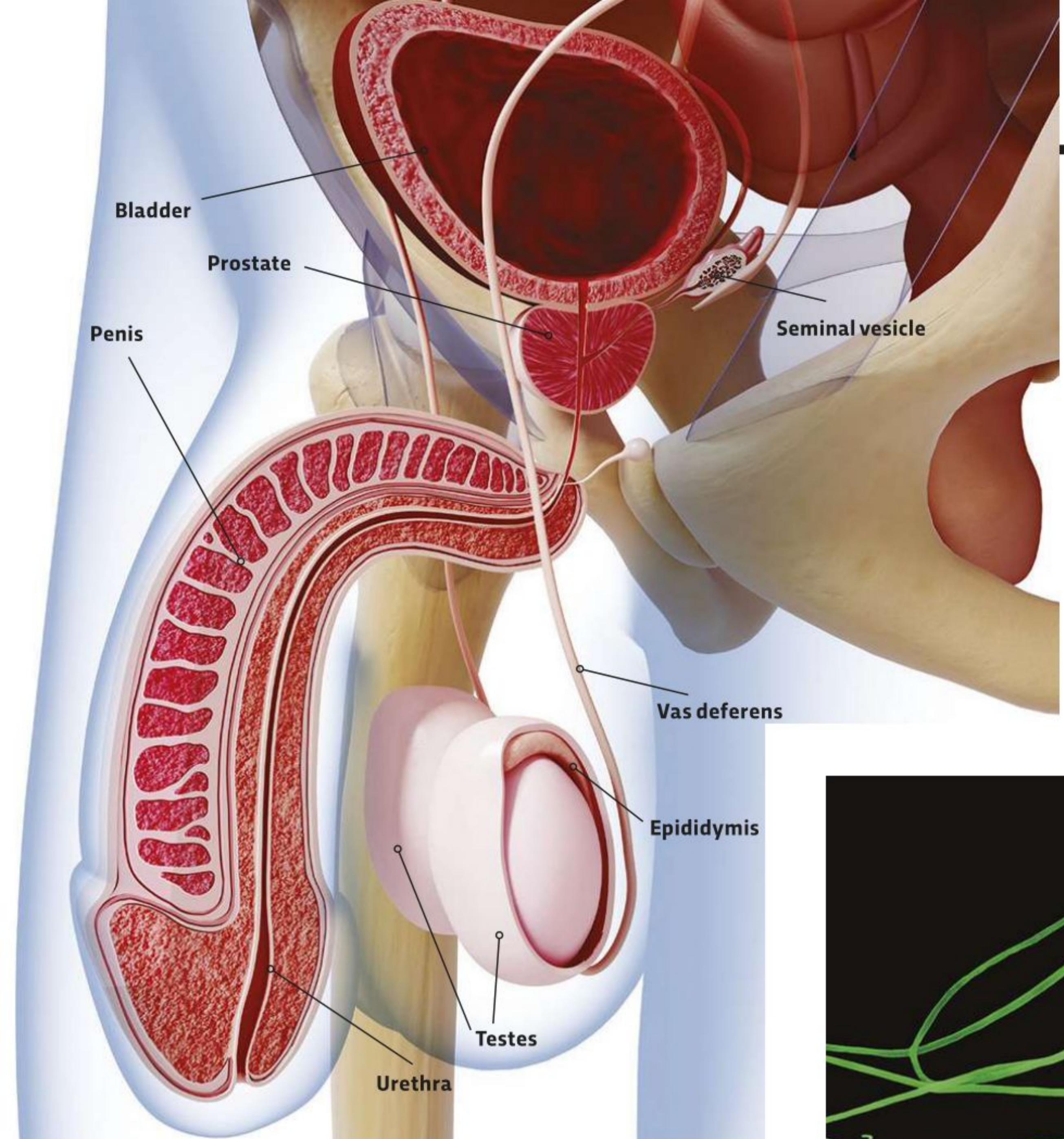
1. Enovid (called Enavid in the UK) was the first hormonal female contraceptive pill. Modern pills contain much lower doses of hormones than earlier versions

2. Arguments for the male contraceptive pill have been raging for many years – this prototype is from 2001

3. A social worker discusses the contraceptive pill with a client in 1970

4. Dr Gregory Pincus worked on developing the first female contraceptive pill and also realised that male hormones could switch off sperm production in men

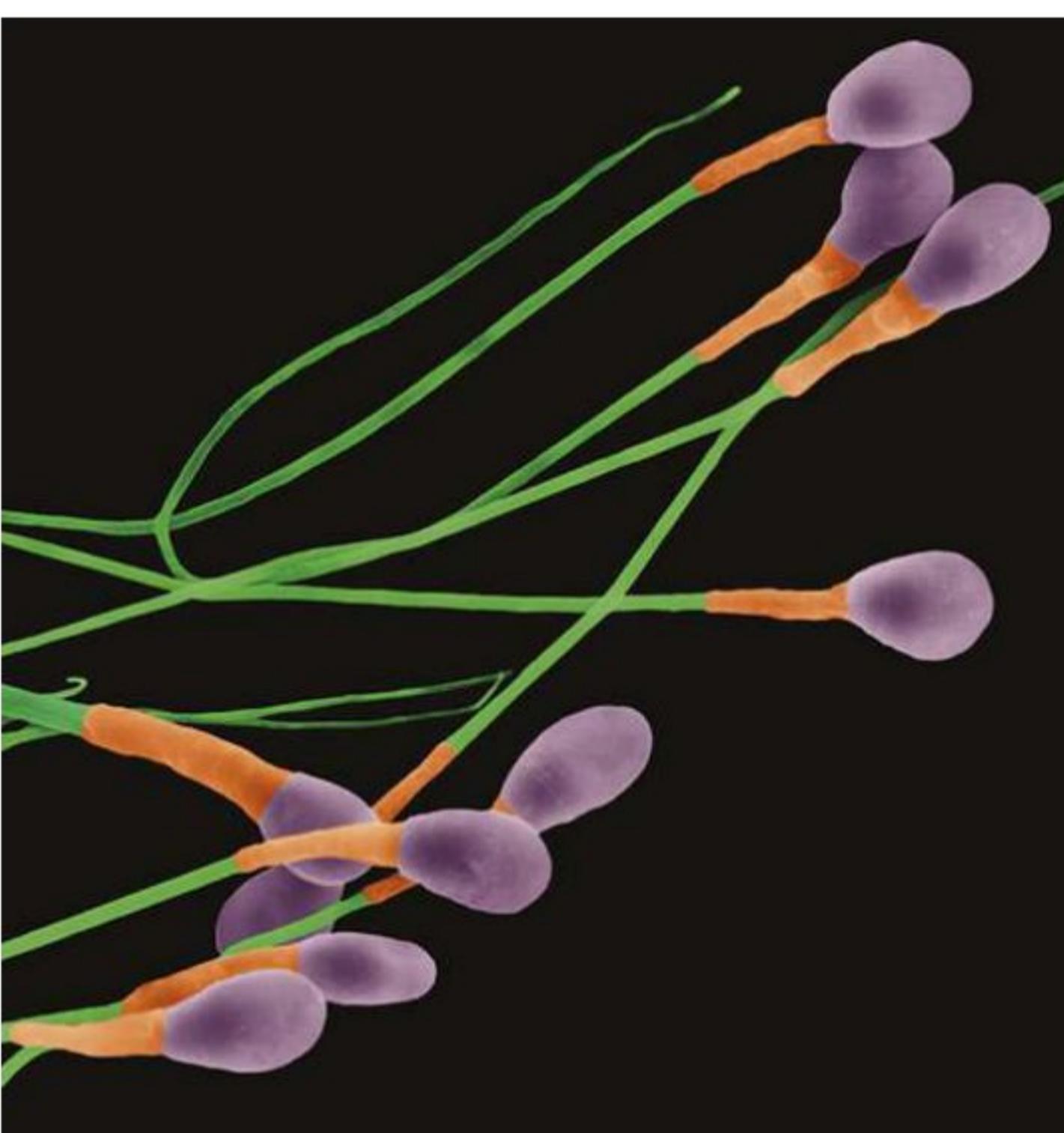
5. Crystals of testosterone, the male sex hormone



RIGHT: Male pills tend to either prevent sperm from developing in the testes, or somehow impede their movement so they can't reach the egg

“It turned out that we’d found a very potent compound that had high activity even at low doses and could be given orally – it was pretty exciting for us to get it right on the first attempt!” she laughs.

At the moment the researchers have only tested their new drug in animals, but it seems to reduce sperm mobility by around 50 to 60 per cent. However, there are still a few issues that Georg and her colleagues need to address before they can move forward into human trials. For a start, they want to develop an even more potent version of the drug which would still be effective at smaller doses. The next step is to carry out long-term animal mating studies to see how well it works to prevent pregnancies and whether there are any hidden side effects. More importantly, they also need to make sure that the drug is reversible and doesn’t cause any birth defects or other health concerns in the subsequent offspring – problems that would rule out any chance of it moving forward.



HORMONE-FREE

Another option is to interfere with the internal ‘plumbing’ of the testes, so that sperm cannot be pumped out during ejaculation. To investigate this idea further, Prof Sab Ventura and his team at Monash University in Australia have just received a \$150,000 grant from the Male Contraception Initiative – a non-profit organisation dedicated to promoting public awareness of male contraceptives.

“Before ejaculation, sperm is moved from the testes to the end of the penis along a tube called the vas deferens,” Ventura says. “We’re trying to disrupt

the nerve signals that tell the muscles around the vas deferens to contract, so that the man still has a pleasurable orgasm but no sperm come out.”

In order to do this, Ventura is investigating a combination of drugs that would completely block both of the types of nerve signals received by the vas deferens, which are sent through neurotransmitter chemicals called ATP and noradrenaline.

“Our approach is non-hormonal so it won’t have any of the unacceptable side effects that have been

seen in the trials of hormone pills,” he says. “It doesn’t affect sperm development, just the plumbing, and we can show that the sperm are still fine and can be used to fertilise eggs in vitro. So we think it’s highly likely to be reversible and that there’s a low chance of causing deformities in babies further down the track.”

Despite the progress in research, there’s no chance of a male pill taking off if there is no market for it. In 2011, Cambridge-based social scientist Dr Susan Walker surveyed attitudes towards the male pill in a group of 54 men and 134 women, all of whom were already using some form of contraception. Just under half the respondents said they would be happy to take a male pill although worries about health risks and effects on long-term fertility also came up. However more than 40 per cent worried about forgetting to

“Even though many men say they would happily take the pill, there are still significant hurdles to be overcome”

take it, with women more concerned about this than men. Larger studies across several continents have come to broadly similar conclusions, showing that men have a preference for contraceptive pills rather than jabs or other delivery methods.

MALE MARKET

Even though many men say they would happily take the pill, there are still significant regulatory and financial hurdles to be overcome. Because there are no male contraceptives currently on the market, regulatory agencies like the FDA are unsure as to how to measure the effectiveness and acceptability of a male contraceptive drug. And although there's a large potential market for an effective male pill, pharmaceutical companies are unwilling to make the hefty investment required to push a candidate pill through large-scale clinical trials in order to get approval.

According to Walker, this all comes down to the difference in risk between male and female contraception. "A person who takes the female pill is the one who will be affected physically and biologically by an unplanned pregnancy. A man is not directly and physically affected by pregnancy – although he may be socially, psychologically and financially affected – so we're working in a different framework for risk," she says, pointing out that childbirth still carries a small chance of serious health problems and even death.

"We have to judge whether the health risks of any type of contraception outweigh risks of pregnancy based on the health of that individual and any other conditions they might have. That nuanced calculation of risk hasn't had a chance to take place around the male pill, because we're not at that stage yet," she adds.

Any contraceptive pill can't prevent sexually transmitted diseases, so condoms will still be a necessity in encounters where that is a risk. But ultimately, the search for the male pill is all about empowering men who want to play their part in preventing pregnancy and providing more options, particularly for couples where the woman is unable to use other forms of contraception.

"We think the time is right to move this forward because men are more open to rethinking social responsibility and what they want out of a relationship, and even protect their own fertility," says Page. "We're underestimating that men want to be more involved – it's just they have such crummy choices. This is all about having more options, so what will really drive it is demand from men to have more control and share the responsibility for preventing unplanned pregnancies." **F**

Dr Kat Arney is a freelance writer and editor. She tweets from @Kat_Arney

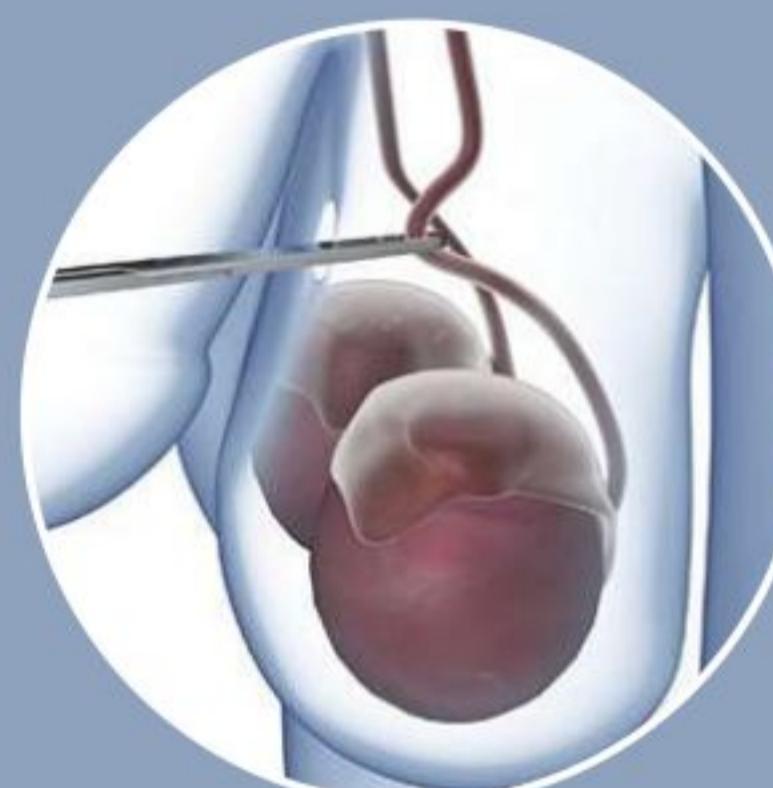
POPPING PILLS AND PLUGGING THE PLUMBING

Here are some alternative ideas for male contraception coming down the pipeline...



1 HERBAL REMEDIES

Gendarussa (also known as gandarusa) is a compound from the Chinese *Justicia gendarussa* plant, which is thought to disrupt fertilisation. It's currently being tested in small trials in Indonesia to see whether it is safe and effective. Another potential contraceptive is pristimerin, which comes from an ancient medicinal herb known as the thunder god vine.



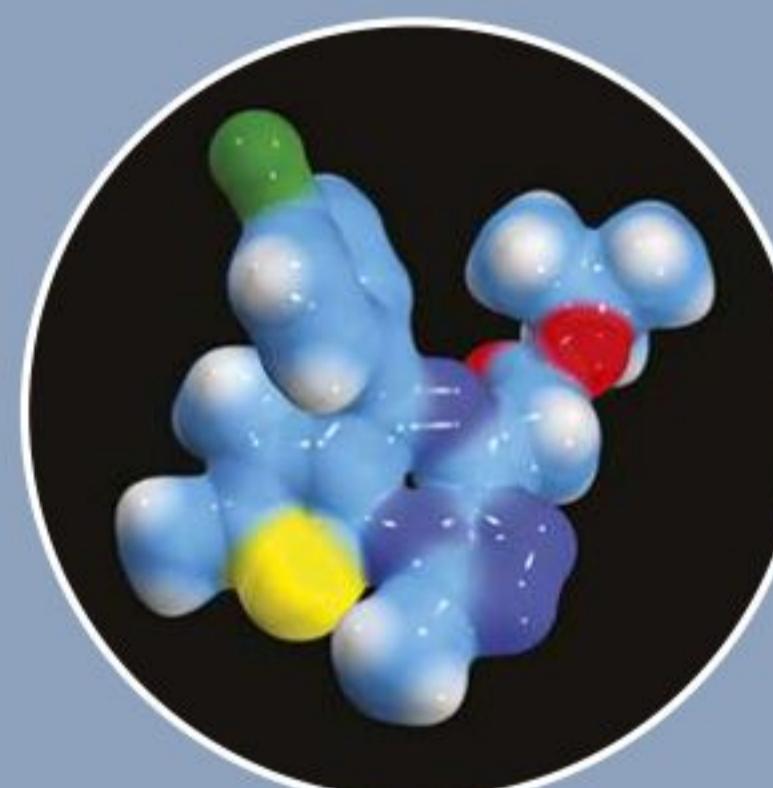
2 VAS-OCCULSION

Vas-occlusion techniques physically block sperm from moving along the vas deferens – the tube that transports them from the testes to the penis – by using injectable polymers that can be reversed at a later date by injecting a 'dissolver' chemical or using ultrasound. The best-known of these techniques is called Vasalgel, which has been successfully tested in monkeys and is expected to move forward into clinical trials shortly.



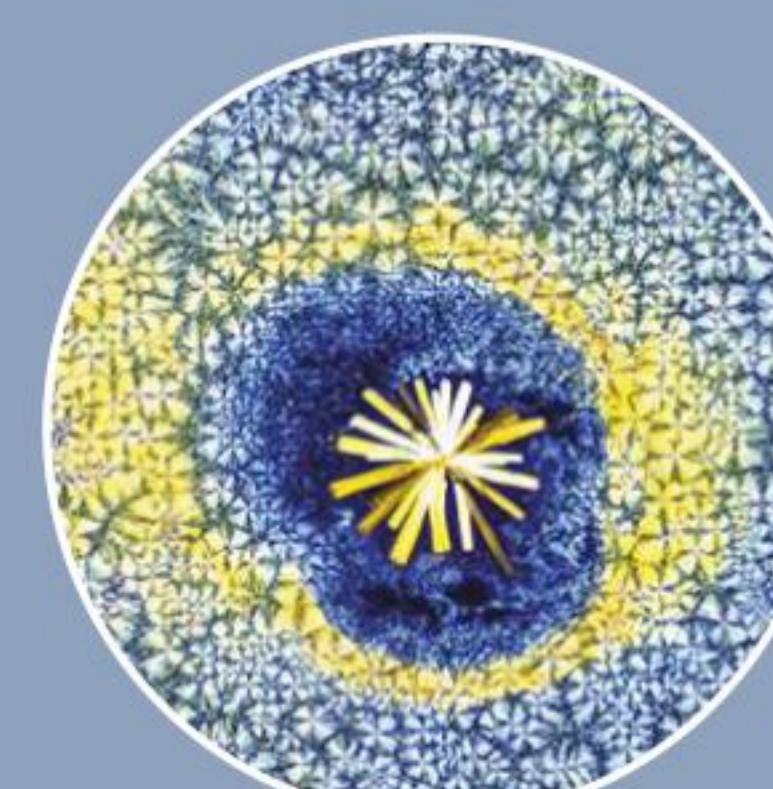
3 CLEAN SHEETS PILL

An experimental drug that paralyses the muscles which squeeze sperm out of the vas deferens, resulting in a 'dry' orgasm. It's being developed by Nnaemeka Amobi, formerly a researcher at King's College London, but has stalled due to lack of funding.



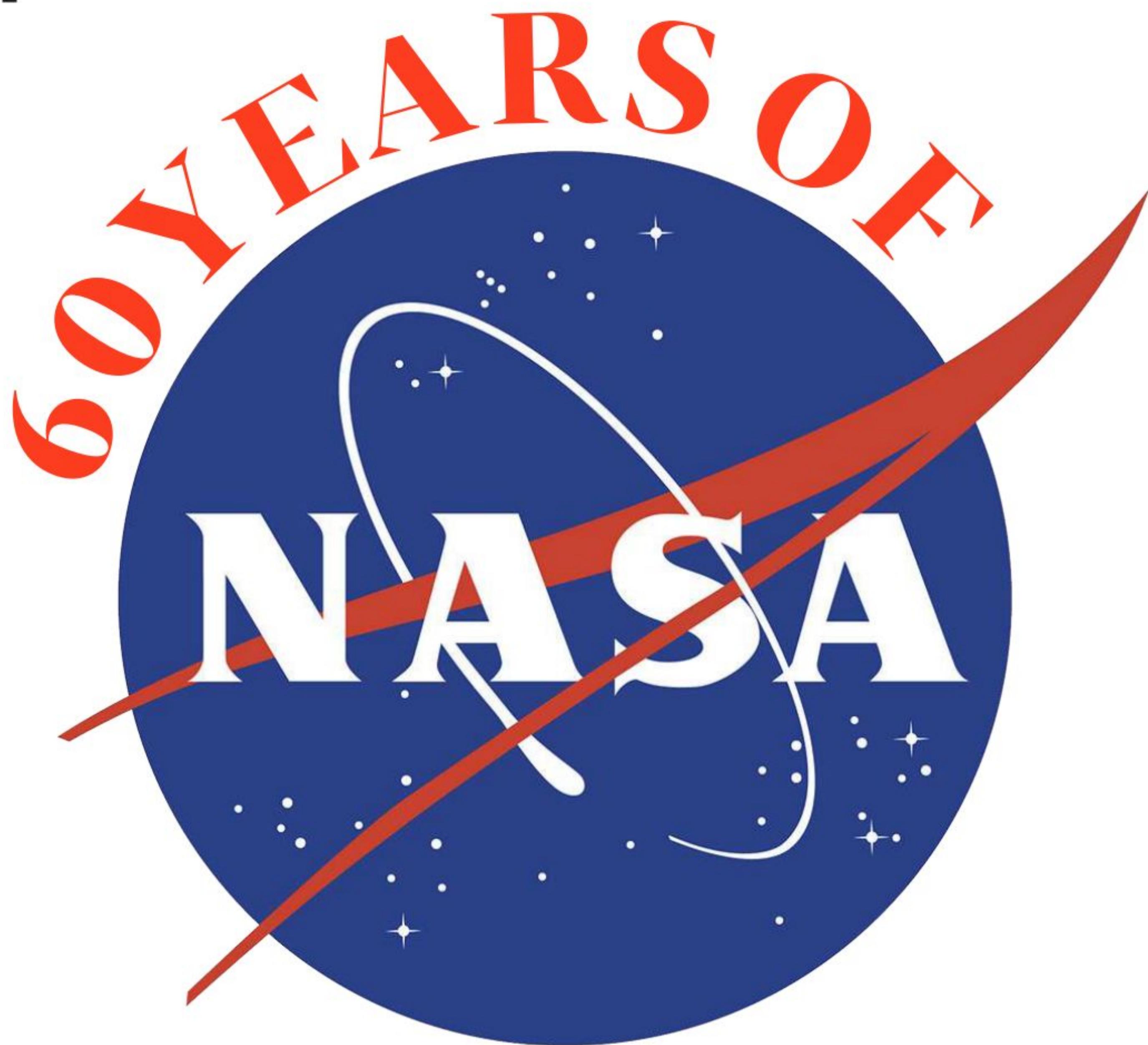
4 JQ1

JQ1 was initially developed as a drug that specifically targets a faulty molecule that drives a rare type of cancer called NUT midline carcinoma. But it also stops sperm from developing properly by blocking a molecule that is essential for packaging up DNA inside sperm.



5 RETINOIC ACID

Sperm production depends on a steady supply of retinoic acid, a chemical produced when vitamin A is broken down in the body. Controlling how retinoic acid is produced and used in the testes, perhaps by blocking the enzymes that break down vitamin A, could lead to new ideas for male contraceptives.



We look back at the space agency's illustrious history, through 20 of its most iconic moments

WORDS: AMY SHIRA TEITEL IMAGES: NASA



29 JULY 1958

PRESIDENT EISENHOWER CREATES THE AGENCY

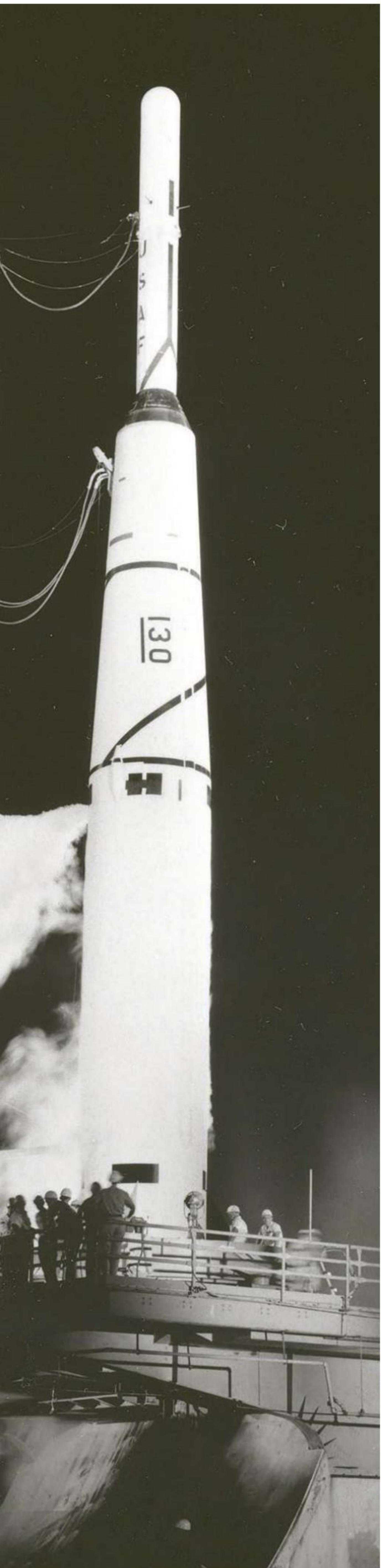
After the Soviet Union launched Sputnik, it fell to President Eisenhower (centre) to soothe the fear that was gripping his nation. Knowing space could soon become a battleground in the burgeoning Cold War, he decided to establish a civilian space agency such that space exploration could be a peaceful endeavour for humanity. He signed the National Aeronautics and Space Act on 29 July 1958, formally putting the National Aeronautics and Space Administration under the leadership of administrator T Keith Glennan (right) and deputy administrator Hugh L Dryden (left).

11 OCTOBER 1958

NASA LAUNCHES FIRST SPACECRAFT, PIONEER 1

Less than two months later, the agency launched its first spacecraft: Pioneer 1. This probe was designed to study the ionising radiation, cosmic rays, magnetic fields and micrometeorites in the space around the Earth and Moon. A mechanical problem meant that it never reached the Moon, but it did return useful data on the environment around the Earth.





9 APRIL 1959

NASA ANNOUNCES ITS FIRST ASTRONAUTS, THE MERCURY 7

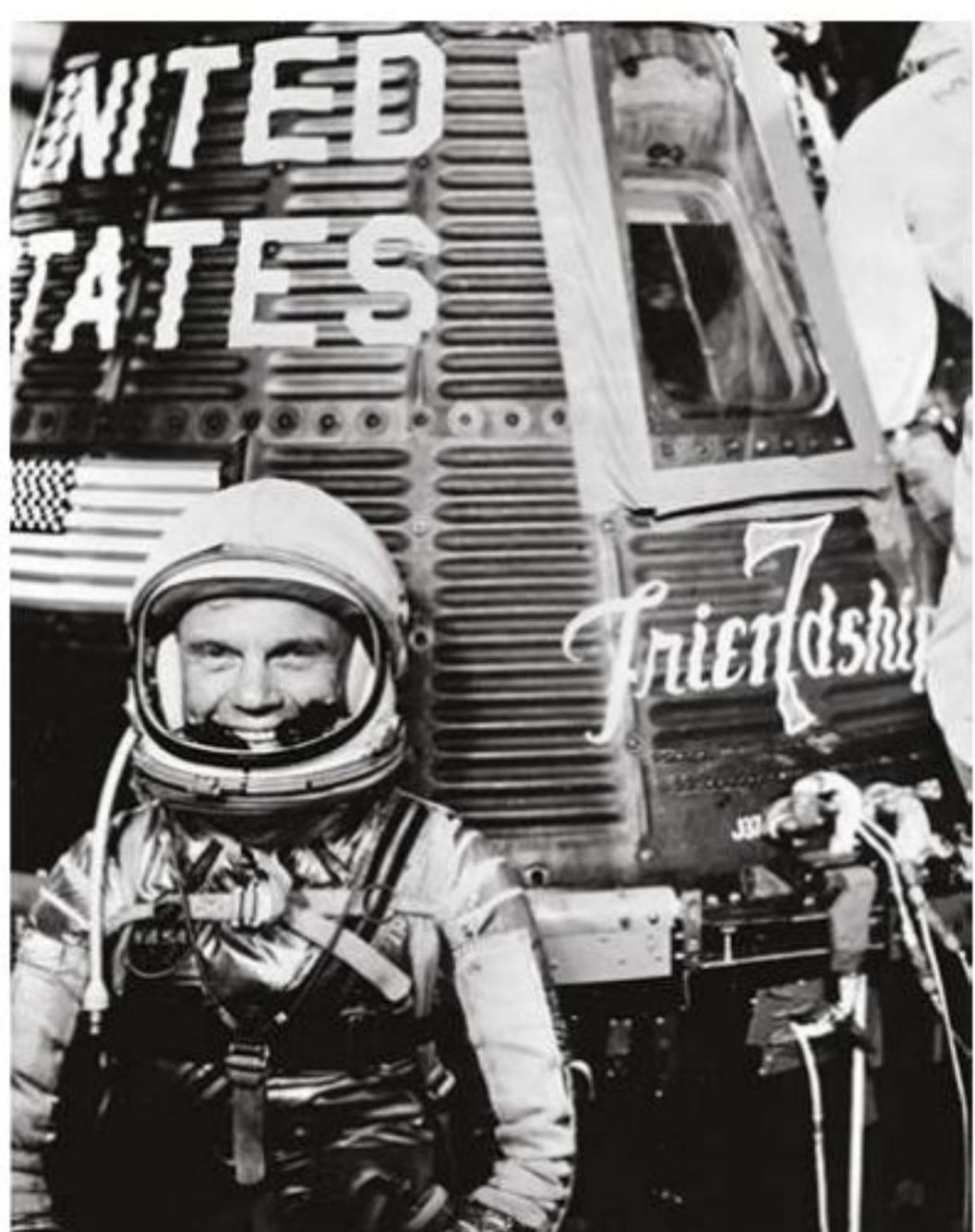
NASA's unofficial goal when it was conceived was to put an American in space before the Soviet Union launched a cosmonaut. For this, America needed astronauts. Exhausting and thorough medical and psychological testing found seven men – all experienced military pilots with combat experience – to be the best suited for the job. When they were introduced to the public in April 1959, they were immediate heroes.



25 MAY 1961

PRESIDENT KENNEDY ANNOUNCES GOAL OF LANDING A MAN ON THE MOON

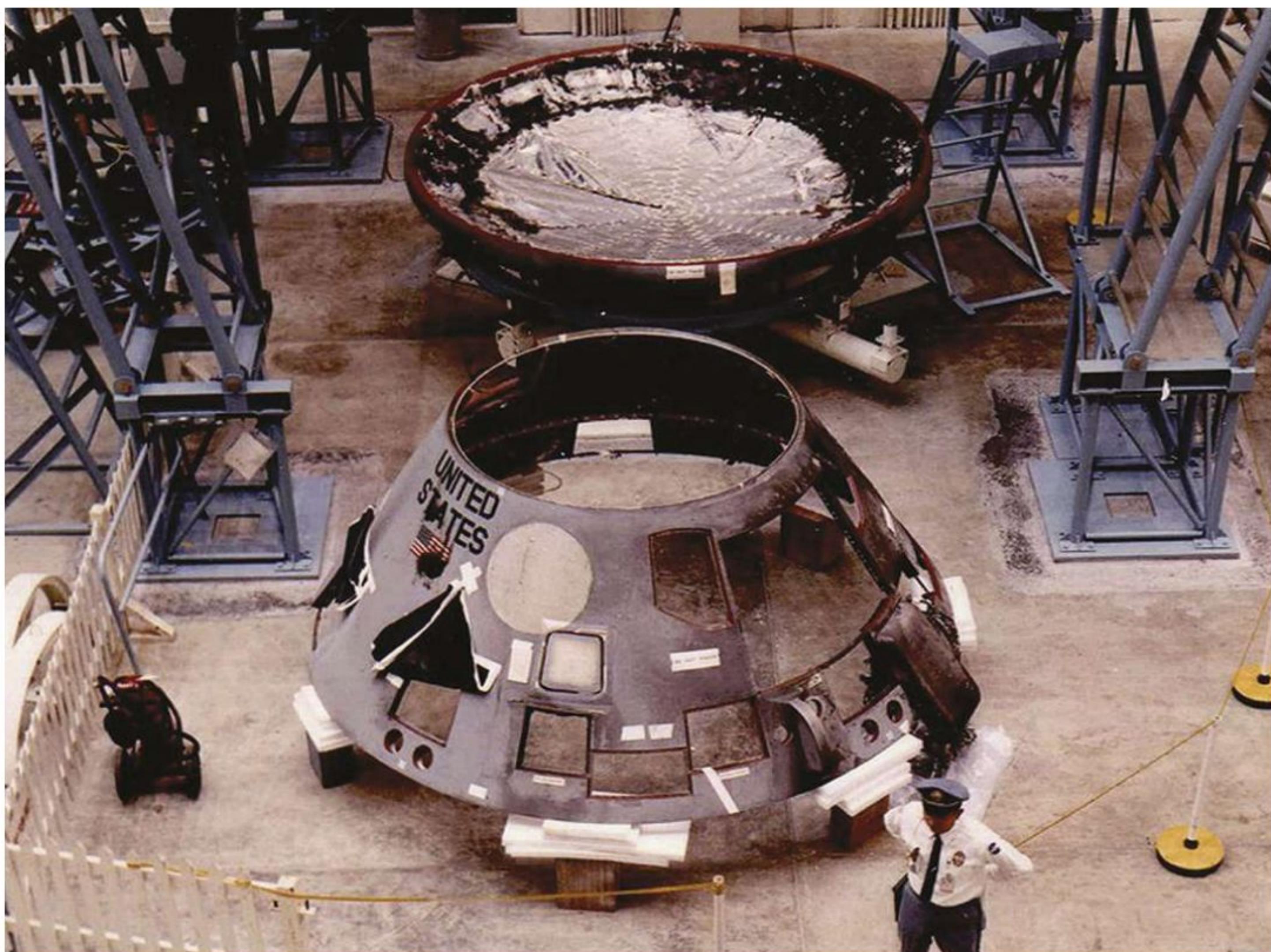
The Soviet Union scored a series of firsts over the United States, including putting the first satellite and the first man into space. Seeking to level the playing field, President Kennedy consulted with NASA and learned that all studies said a Moon landing within the decade was possible. With 15 minutes of suborbital spaceflight under America's belt, he publicly promised a man on the Moon in a famous address to Congress.


20 FEBRUARY 1962
FIRST AMERICAN IN ORBIT

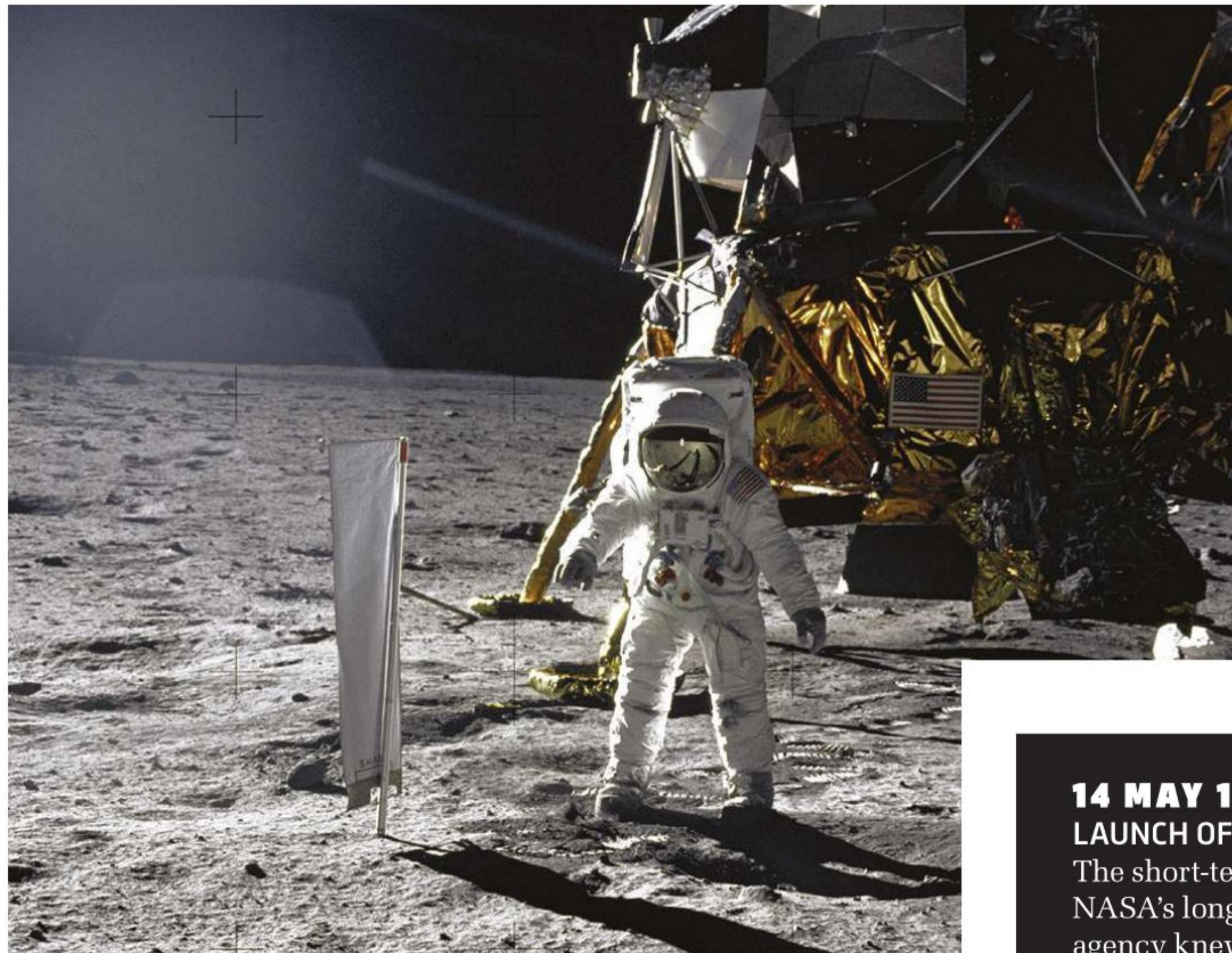
NASA originally planned a slow and steady approach, with each astronaut making a suborbital flight before anyone would go into orbit. But with the Soviets taking such big steps forward, NASA changed its plan. The third of the manned Mercury missions was its first orbital flight. John Glenn made three loops around the Earth in a journey that lasted 4 hours and 56 minutes, before splashing down in the North Atlantic Ocean.

3 JUNE 1965
FIRST AMERICAN SPACEWALK

In early 1965, the Soviets scored another first with the first spacewalk. In response, NASA secretly trained astronaut Ed White to walk in space, before adding it as an official mission objective not two weeks before the launch of the manned Gemini 4 flight. During his 20 minutes outside the spacecraft, White manoeuvred around by using a compressed oxygen gun.


27 JANUARY 1967
APOLLO 1 FIRE

By the late 1960s, NASA was moving from launch to launch like clockwork. But during a routine launch rehearsal test for the first Apollo mission, a fire broke out in the pure-oxygen environment, killing astronauts Gus Grissom, Ed White and Roger Chaffee. It was a sobering event for NASA and America: a grim reminder that spaceflight is difficult and dangerous. Following a months-long investigation wherein the spacecraft was disassembled piece-by-piece, NASA almost entirely rebuilt the command module into a far safer and more reliable spacecraft.

**20 JULY 1969****FIRST HUMANS ON THE MOON**

Everything that NASA had been working on for nine years came together on Apollo 11. Though America was wrapped up in the Vietnam War and protesters slammed NASA for spending money on a project many considered frivolous, when Neil Armstrong and Buzz Aldrin took their first steps on the Moon the nation was briefly united as President Kennedy's promise was fulfilled.

**13 APRIL 1970****APOLLO 13'S 'SUCCESSFUL FAILURE'**

During NASA's third lunar landing mission, Apollo 13, things quickly got interesting after an oxygen tank ruptured 55 hours into the flight.

Trusting their instincts and each other in equal measure, the crew and mission controllers repurposed the lunar module into a lifeboat. Here, Jack Swigert can be seen holding the makeshift apparatus that the astronauts assembled in order to remove excess carbon dioxide from the lunar module, keeping them alive. When they returned safely, the world rejoiced.

14 NOVEMBER 1971**MARINER 9 REACHES MARS**

In the background of NASA's more visible push to send people to the Moon was the intense interest in sending spacecraft to other planets. Among the first targets was Mars with the Mariner program. After a handful of failed and partially successful missions, Mariner 9 revealed our planetary neighbour in stunning detail. The first spacecraft to orbit another planet, it mapped 70 per cent of the Martian surface.

**14 MAY 1973****LAUNCH OF SKYLAB**

The short-term Apollo missions were never NASA's long-term goal. From the start, the agency knew a more permanent base in space was the key to exploration. The first iteration of this goal was Skylab. Essentially a hollowed-out rocket stage, the station hosted three crews between 1973 and 1975, who ran experiments to prove that humans could adapt to microgravity and live in space for months at a time.




5 SEPTEMBER 1977
LAUNCH OF VOYAGER 1

Another part of NASA's early interest in planetary exploration were the four distant gas giants. Engineers realised that these planets were aligning so perfectly that all four could be explored with one mission, so this once-in-175-years chance was too good to pass up. Launched in 1977, the twin Voyager spacecraft both flew by Jupiter and Saturn, with Voyager 2 passing Uranus and Neptune as well.


18 JUNE 1983
FIRST AMERICAN WOMAN IN SPACE

Another change at NASA as it developed the Space Shuttle was the inclusion of women in the astronaut corps. Six women were admitted into the 1978 astronaut class, and in June 1983, Dr Sally Ride became the first American woman in space, flying as a mission specialist on STS-7.

12 APRIL 1981

FIRST ORBITAL FLIGHT OF THE SPACE SHUTTLE

With the lunar landing missions done and deep-space missions unlocking planetary secrets, NASA returned to a pre-Apollo vision: routine spaceflight. The agency needed a relatively cheap, reusable spacecraft and the result was the Space Shuttle, a new workhorse that promised to make spaceflight as routine as air travel. The first mission (STS-1) marked NASA's triumphant return to manned missions.



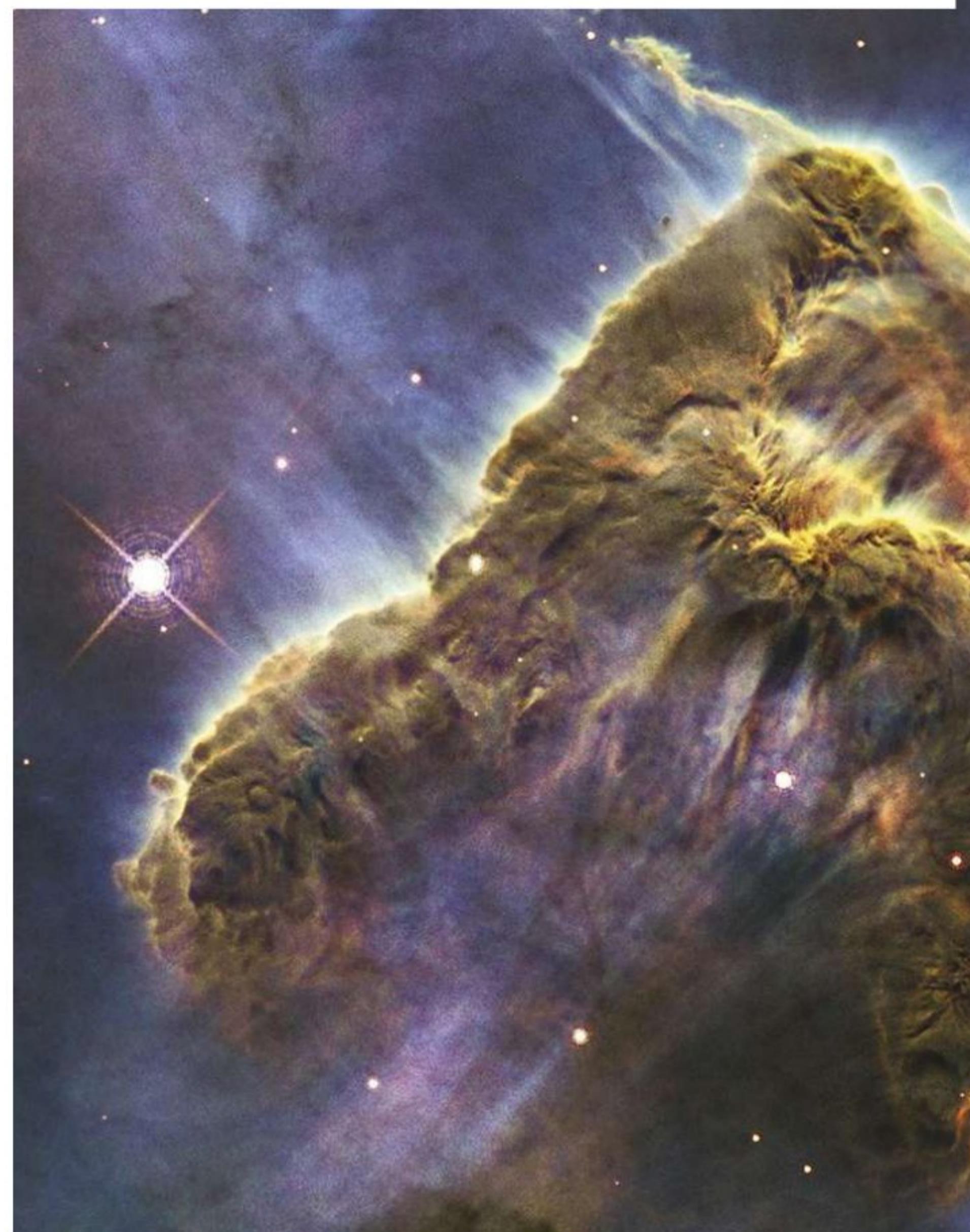
28 JANUARY 1986

CHALLENGER DISASTER

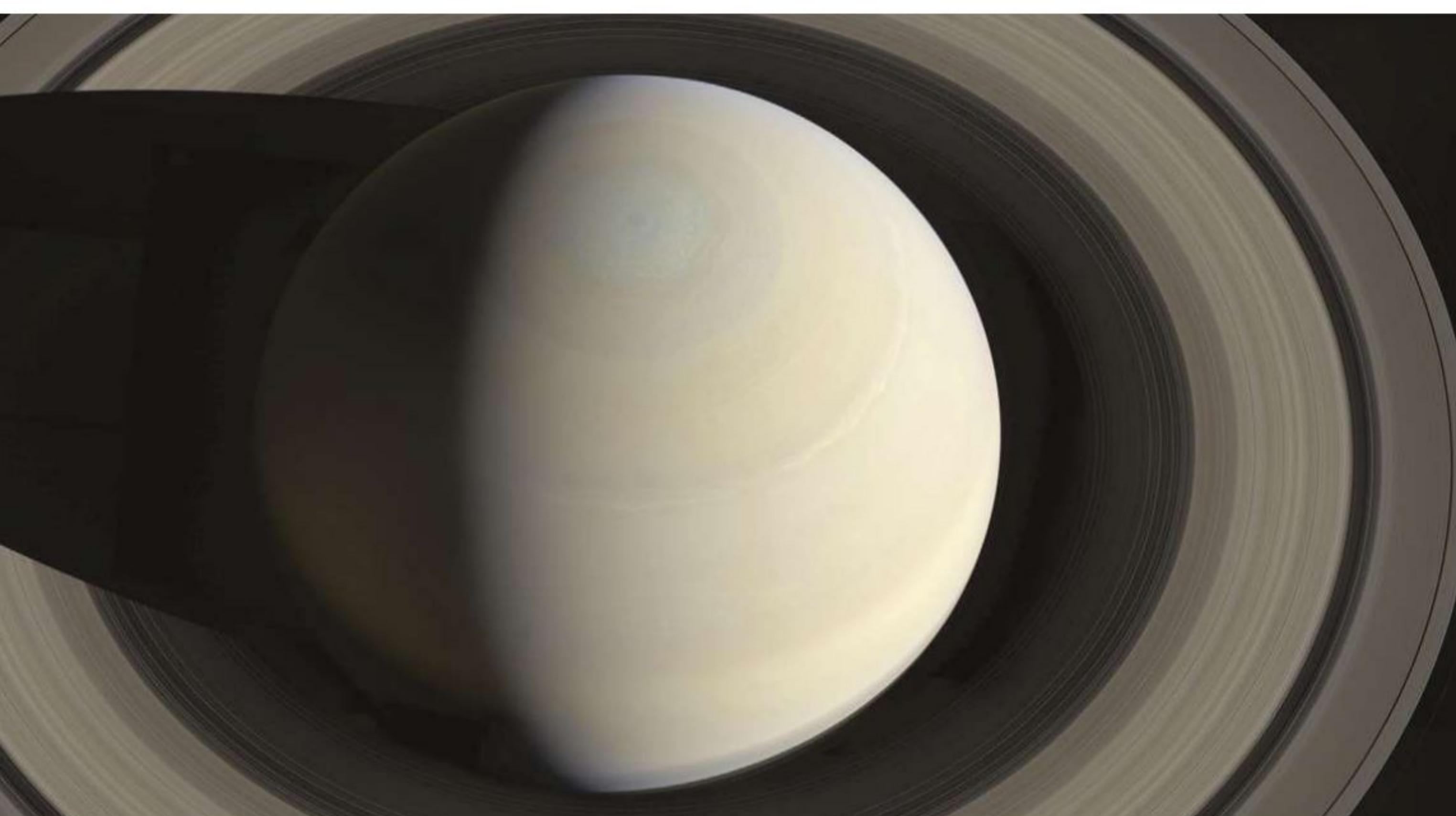
The 25th mission of the Space Shuttle program (STS-51-L) was capturing imaginations. On the crew was Christa McAuliffe, set to become the first teacher in space. Teachers across the nation put their lessons on hold so students could watch the launch live. But excitement turned to horror as, 73 seconds into its flight, Challenger broke apart. The crew of seven was killed and the grotesque, Y-shaped explosion dominated the news for days to come.

25 APRIL 1990**HUBBLE SPACE TELESCOPE DEPLOYED**

Once the Shuttle resumed flying, science missions were back on. The Hubble Space Telescope launched as the payload of STS-31 in April 1990. From its position in orbit, floating some 547km (340 miles) above Earth, Hubble can see things in the Universe that we could previously only dream of. One of the most famous examples is this picture that Hubble took of the distant Carina Nebula, where radiation and streams of charged particles shape and compress the pillars of gas and dust.

**1 JULY 2004****CASSINI ENTERS ORBIT AROUND SATURN**

NASA hasn't limited its international collaborations to the International Space Station. Planetary missions are benefitting from partnerships, too. Notably the Cassini-Huygens mission, a joint flight to Saturn with the European Space Agency (ESA). The Huygens probe successfully landed on Saturn's moon Titan while Cassini, in addition to gathering data for 13 years at Saturn, took some of the most stunning images of the ringed planet.



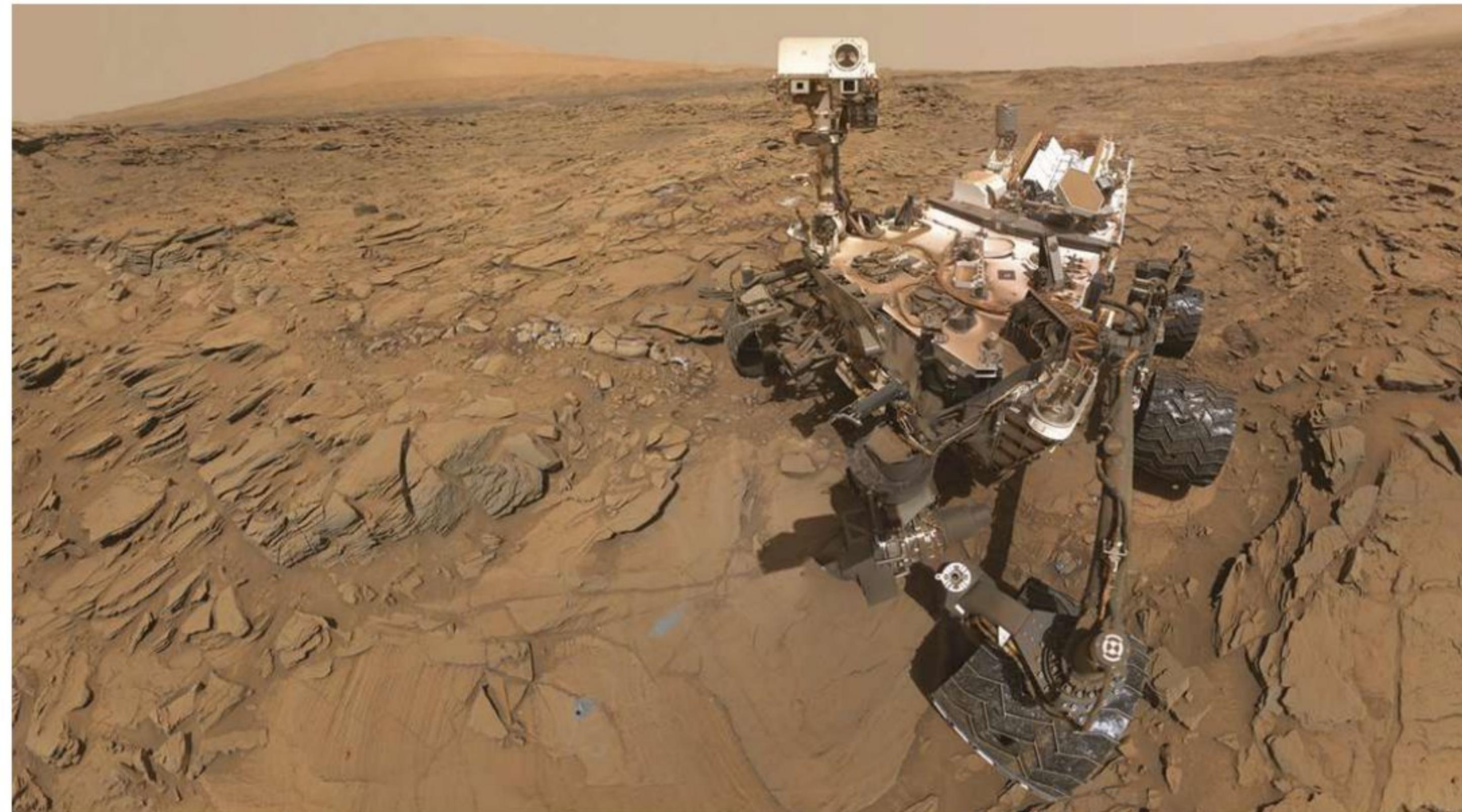


6 DECEMBER 1998 CONSTRUCTION OF THE INTERNATIONAL SPACE STATION BEGINS

After decades of competition, the United States and Russia began a truly collaborative era in space with the construction of the International Space Station. The Russian Zarya module was the first to reach orbit in November 1998 and then in December the crew of STS-88 arrived with the US-built Unity node (seen here). Over 55 missions later, the station has hosted more than 220 astronauts from 18 countries.

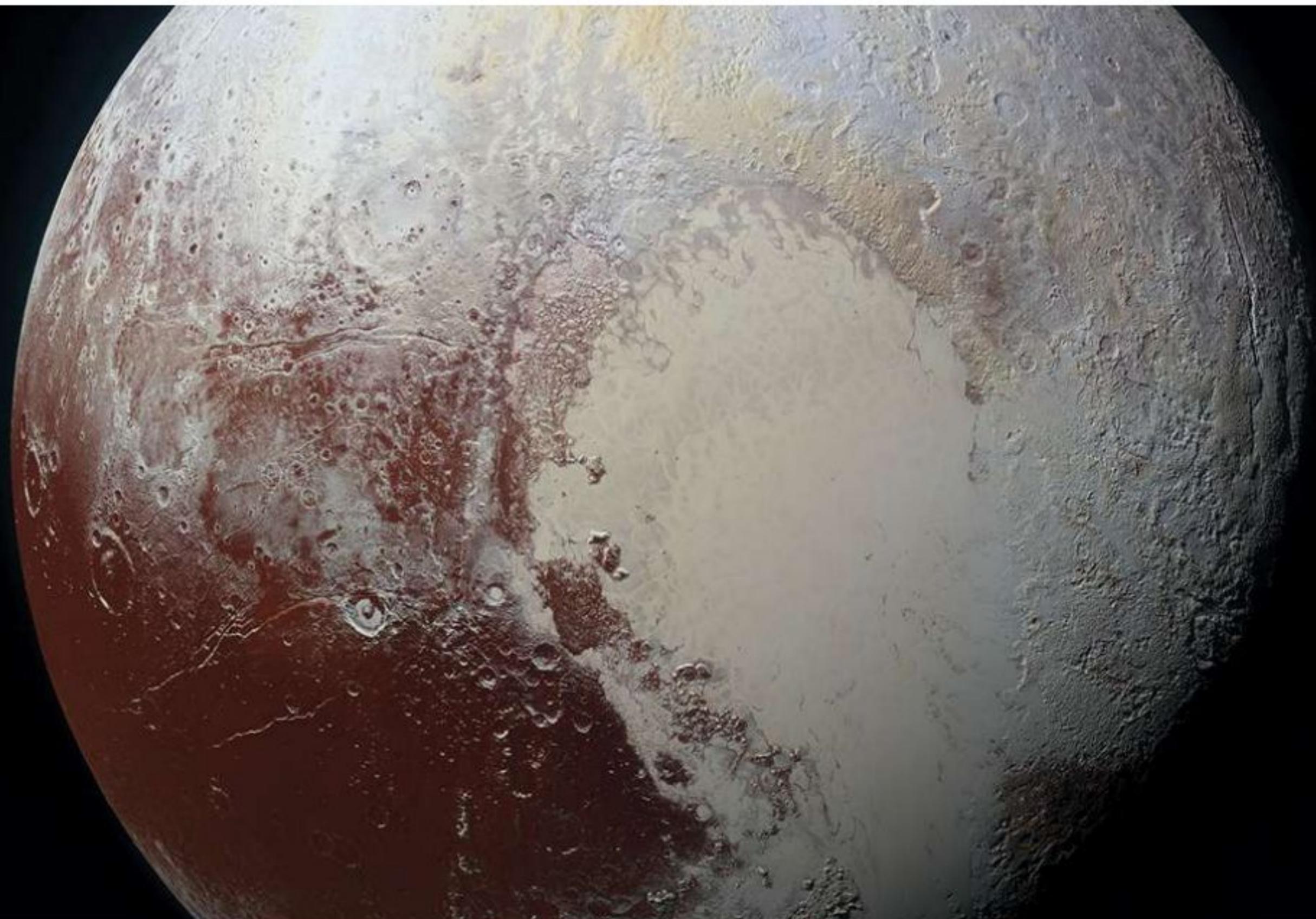
6 AUGUST 2012 CURIOSITY ROVER LANDS ON MARS

NASA never lost its early fascination with Mars. After first landing on the surface in the 1970s, the agency delivered the car-sized Curiosity rover to the Red Planet in 2012. This roving chemistry lab, which can also take incredible selfies, has the most advanced suite of instruments ever sent to another planet. Analysing rocks and dust, it's still working to determine whether ancient Mars was a habitable planet.



14 JULY 2015 NEW HORIZONS FLIES BY PLUTO

Whether or not you consider Pluto to be a planet, finally visiting this icy world was an exciting moment for planetary enthusiasts. The nine-year New Horizons mission was the first time we had not only explored but also seen the distant Kuiper Belt object up close, finishing the first generation of Solar System exploration.



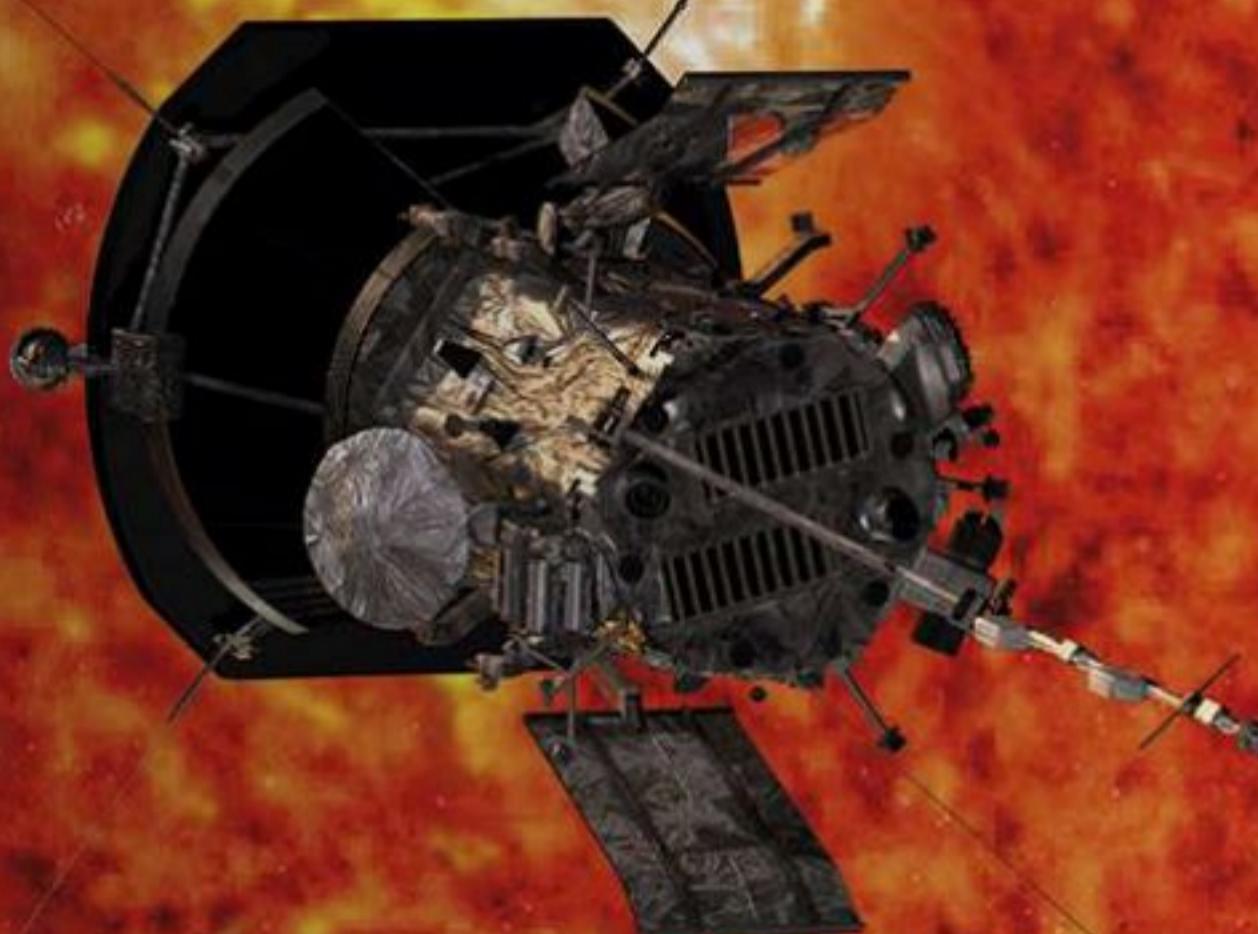
A GLIMPSE OF THE FUTURE

10 upcoming NASA missions to get excited about

PARKER SOLAR PROBE

LAUNCH DATE: SUMMER 2018

Though we see it (almost) every day, the Sun is still a mystery. The Parker Solar Probe will take our first up-close look of our nearest star, approaching to within 6.1 million kilometres of the surface – more than seven times closer than any spacecraft has been before. This will take it through the Sun's corona and should revolutionise our understanding of solar weather.



ORBITING CARBON OBSERVATORY 3 (OCO-3)

LAUNCH DATE: TBC 2019

The third in a series of space instruments, OCO-3 will study the distribution of carbon dioxide on Earth, showing us the real impact of growing urban populations and increasing fossil fuel combustion. NASA plans to assemble the instruments from spare parts of its predecessor, OCO-2, before hosting it in the Japanese Experiment Module on board the International Space Station.

EUCLID

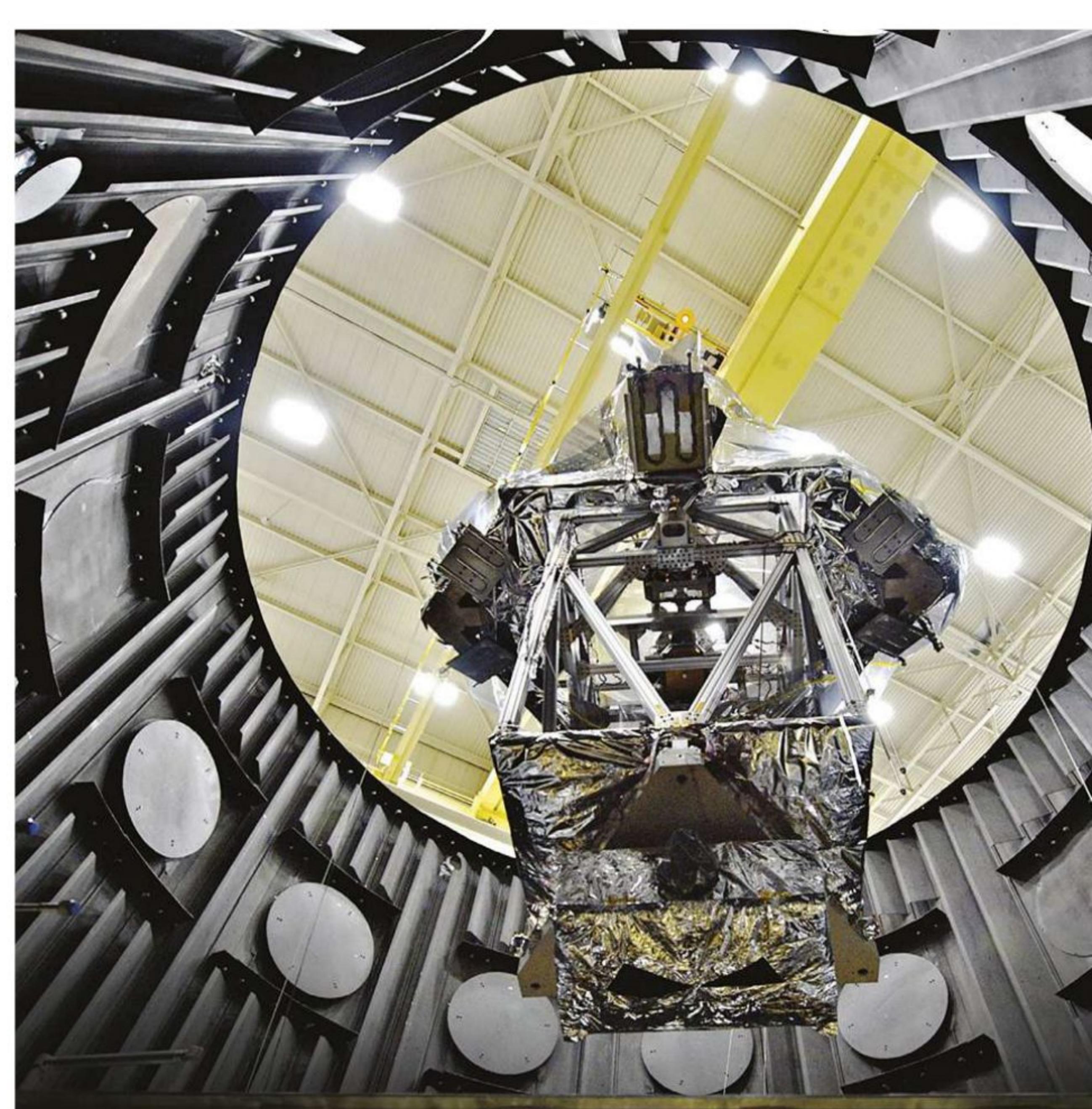
LAUNCH DATE: 2021

An ESA mission, but with significant contributions from NASA, Euclid will investigate dark matter and dark energy – critical components of our Universe that are shrouded in mystery. Using its 1.2m-diameter telescope, as well as infrared detectors, Euclid will attempt to measure the accelerating expansion of the Universe, in the process shedding light on these phenomena.

ORION SPACECRAFT

FIRST UNMANNED LAUNCH: JUNE 2020

The first spacecraft purpose-built to leave low Earth orbit since Apollo, Orion will carry humans farther than we've ever gone before, to Mars and beyond. It'll launch on NASA's own Space Launch System: the modular heavy-lift rocket that will out-power the Saturn V. The first test flight was in December 2014, with an uncrewed lunar orbital flight planned for 2020.



JAMES WEBB SPACE TELESCOPE

LAUNCH DATE: MARCH 2021

The largest telescope ever sent into space, JWST will usher in a new era of space exploration. Once it arrives at its final destination some 1.5 million kilometres away, it'll begin to look at the Universe in infrared light (unlike Hubble, which sees in visible light), allowing us to look further back in time than ever before.

MARS 2020 ROVER

LAUNCH DATE: SUMMER 2020

Based on the highly successful Curiosity rover, the Mars 2020 mission will carry more sophisticated science instruments and upgraded hardware. Not only will it look at whether Mars is a habitable environment now, it'll be the first mission to look directly for signs of ancient life on Mars.



WIDE FIELD INFRARED SURVEY TELESCOPE (WFIRST)

LAUNCH DATE: MID 2020s

WFIRST is a new space-based observatory designed to answer a host of scientific questions. Its primary mirror is 2.4m in diameter – the same size as Hubble's – and this will feed data to two instruments: a high-resolution camera and a coronagraph. As well as studying dark energy, measuring the expansion of the cosmos, WFIRST will also be looking for exoplanets, finishing the work begun by NASA's Kepler telescope.



EUROPA CLIPPER

LAUNCH DATE: SOMETIME IN THE 2020s

One of the most compelling spots in our Solar System is Jupiter's moon Europa, which is home to a vast subsurface ocean. Europa Clipper will be the first mission to undertake a dedicated exploration of the icy moon while orbiting Jupiter. With its suite of nine science instruments, including cameras and spectrometers, it'll investigate whether the moon's oceans contain the right conditions to support life.

MULTI-ANGLE IMAGER FOR AEROSOLS (MAIA)

LAUNCH DATE: EARLY 2020s

This instrument, carried aboard a satellite stationed in low-Earth orbit, will analyse the sunlight scattered by polluting particles in our planet's atmosphere. This will allow scientists to determine the sizes, compositions and quantities of these particulates, which will then be combined with

population health records in order to build up a picture of how air pollution affects human health on a global level.

PSYCHE

LAUNCH DATE: 2022

Psyche (pictured below) is a mission to visit a metal asteroid orbiting between Mars and Jupiter. The first world examined that isn't made of rock or ice, scientists suspect that the asteroid is actually the exposed nickel-iron core of an early planet – a remnant from the birth of our Solar System. Using an imager, magnetometer and a gamma-ray spectrometer, this mission promises to provide insight into the formation of terrestrial planets.

Amy Shira Teitel is a spaceflight historian and author of *Breaking The Chains Of Gravity* (£9.99, Bloomsbury Sigma).



LOST





For hundreds of years, indigenous knowledge has been pushed aside. But modern science is now listening to this traditional wisdom, as it could help improve our understanding of the planet and the stars

WORDS: DR COLIN BARRAS

BUT NOT FORGOTTEN

B

ack in 1977, scientists made an alarming discovery: the bowhead whale population in the Beaufort Sea to the north of Alaska had collapsed to around 1,000 individuals. It was enough to justify a local ban on whaling.

But Alaska's indigenous whale hunters were baffled – by their own estimates the bowhead population numbered at least 7,000.

The scientists had counted the number of bowheads passing through open water near the coast, assuming that the whales could not swim further offshore beneath the ice. The indigenous hunters insisted that whales routinely swam beneath that ice, breaking it with their heads when they needed air. Bowheads that behaved in this way were not figuring in the scientists' count, according to the hunters.

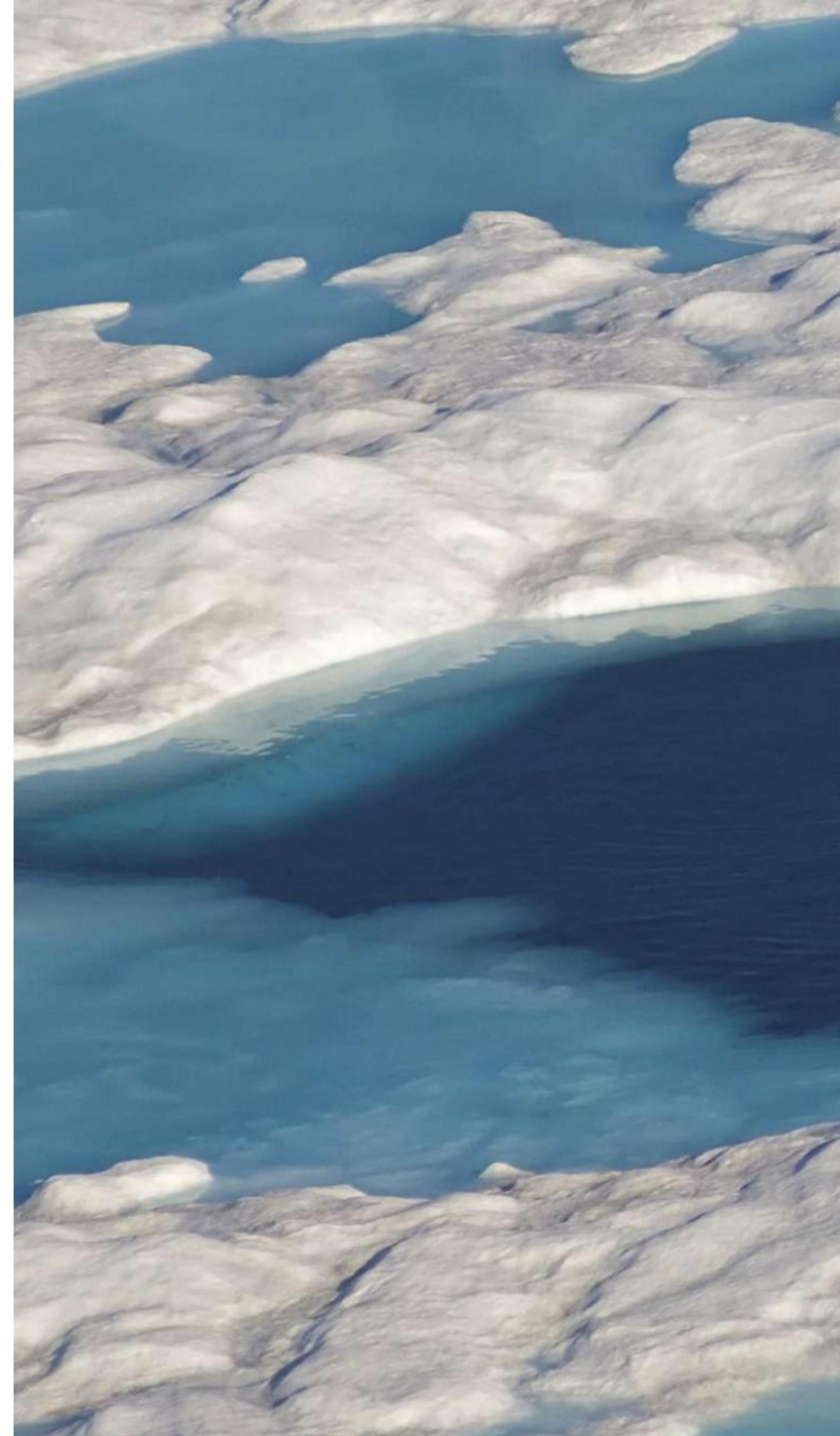
Within a few years scientists had confirmed that the hunters' claims were correct and whaling had resumed on a small scale. A 1991 survey put the whale population at 8,000. It was further evidence that the local hunters had been right to dispute the results of the 1977 survey, even though it had been conducted by highly trained scientists.

What we might label 'modern science' emerged in Europe about 450 years ago, and has since spread throughout the world. It is undoubtedly a powerful tool to better understand life, the Universe and everything – but as Alaska's indigenous hunters realised, modern scientists can reach the wrong conclusions where there are gaps in their knowledge.

“If indigenous people had this knowledge first, why shouldn’t we include that in the history of science?”

RIGHT: Bowhead whales have large heads with thick skulls that allow them to break through sea ice. Indigenous hunters' reports of this behaviour helped confirm population numbers of the bowhead whale

BELOW RIGHT: Astronomer Karlie Noon is interested in making links between modern science and stories from indigenous Australians



Researchers are now recognising that some of those gaps can be filled with information embedded in indigenous knowledge systems. "We're seeing how weaving Western and indigenous scientific approaches together can advance modern science as a whole," says Dr Jesse Popp, an ecologist at Laurentian University and a member of the Wiikwemkoong Unceded Territory in Ontario, Canada.

By embracing that indigenous knowledge, modern scientists are beginning to appreciate something that members of indigenous communities have long known – namely that their ancestors were scientists.

SCIENCE STORIES

It is perhaps easy to understand why indigenous knowledge was ignored. With the arrival of European settlers in the Americas, Africa and Australasia, indigenous communities were often forced from their lands and pushed to the margins of society, their knowledge systems trivialised. "It makes it easier to colonise a people if they are in that degraded position," explains Karlie Noon, an astronomer at the Australian National University in Canberra and a member of the Kamilaroi group of indigenous Australians.



There's also the fact that indigenous knowledge is typically an oral tradition, passed down in the form of stories. There may have been a tendency in the past for modern scientists to dismiss those stories as myths with no practical value – but that misunderstands the true purpose of the tales, explains Dr Ocean Mercier, a lecturer in Māori Science at Victoria University of Wellington, New Zealand, and a member of the Ngāti Porou 'iwi' (tribe). "One way to see the stories is as code," she says. "Within that code, if you know how to unpick it, there's really important information." In other words, the stories are memory aids.

For instance, the Kokatha communities of South Australia told a story of Nyeeruna, a skilled hunter who lives in the sky and is in perpetual pursuit of a group of sisters. It is essentially the same story as the Ancient Greek myth of Orion and the Pleiades – and, indeed, it involves many of the same stars in the night sky.

But the Kokatha story is far more detailed than the Greek version. It goes on to explain how Nyeeruna periodically attempts to attack his quarry: the club in his hand fills with 'fire magic'. One of the sisters then counterattacks with 'fire magic' of her own. ▶





“Inuit communities have a wealth of knowledge about the environment”

• Some astronomers now think the story shows the indigenous Australians had noticed that two of the stars it involves – Betelgeuse and Aldebaran – are variable stars that gradually brighten and dim over several years. Modern scientists failed to realise that Betelgeuse and Aldebaran are variable stars until the 1830s.

“Science is partly about who discovered information first,” says Noon. “Credit needs to be given there: if indigenous people had this knowledge first, why shouldn’t we include that in the history of science?” Australian indigenous astronomical knowledge had been dismissed for so long that Noon was unaware of its existence growing up. It wasn’t until she began her university degree that she first

ABOVE LEFT: The Arctic Eider Society teams young people up with seasoned hunters, so they can learn land-based skills

ABOVE RIGHT: Two hunters observe wildlife in Hudson Bay – their knowledge is helping the Arctic Eider Society to build a database of knowledge that will help chart how climate change is affecting the sea ice

RIGHT: Sanikiluaq elder Jimmy Iqaluq describes a frozen Arctic seascape captured by a drone

encountered some of the ancient stories. But she is now one of a growing number of astronomers who are convinced that Australia’s indigenous communities should be celebrated for the care with which they observed the night sky. “Whole communities are now embracing this, particularly in the Torres Strait,” she says. “They have so much sky knowledge and they still use it daily.”

Dialogues between modern and indigenous science are opening up elsewhere too. Climate change is particularly severe at the high latitudes, but monitoring the changes on the ground poses a logistical challenge for modern scientists – the Arctic region is vast and difficult to reach from the major urban centres where many scientists are based. But the Inuit communities living around Hudson Bay in northeastern Canada spend most of their lives on that land, and they have a wealth of knowledge about the environment as it existed in the past and as it is changing today. Much of the knowledge is unique to local communities, but a new database launched last year by the Arctic Eider Society will make that local knowledge more widely available. The database, which is called Siku (meaning ‘sea ice’), has been dubbed a ‘Wikipedia of Inuit knowledge’. It is a map-based app where locals can upload their personal observations, providing



invaluable data both for modern scientists and for others in the Inuit community.

"It shows you where to go harvesting different animals, where to pick different plants, where the ice is freezing over first in winter and breaking up first in spring," says Caitlyn Baikie, who works for Students on Ice, a Canadian charitable organisation, and who grew up in an Inuit community in Labrador.

Baikie says initiatives like Siku emphasise that indigenous communities can contribute to our understanding of the world. Indigenous science is sometimes dubbed 'traditional knowledge', but she

Nomadic science

One woman is mixing modern and traditional methods to help save her community



Bridging the divide between indigenous and modern was a personal challenge for Hindou Oumarou Ibrahim, pictured. She is a member of Chad's nomadic and semi-nomadic Mbororo community, but she moved into a town as a child because her mother was determined to see her children educated. Not only was Ibrahim teased by the urban children for her Mbororo heritage, she also encountered some hostility when she later returned to her rural homeland.

"When I went back to the community it was: 'oh, the Western girl. You must know more than we do,'" she says. Nevertheless, she was intent on using her education to help the Mbororo. She says climate change is threatening their ways of life. This, in turn, is jeopardising the Mbororo's knowledge of the environment – including, for instance, how observing the behaviour of animals allows

predictions to be made about the quantity of rain to expect in the season ahead.

In 2013 she helped her community formally document their understanding of their environment using modern mapping technology. The project made it easier for local authorities to respect the Mbororo's knowledge. This is helping ensure that their voices are heard when initiatives to adapt to climate change are being planned, which is the best way to make sure their way of life doesn't become lost.

Ibrahim is now publicising the plight of the Mbororo people and their knowledge on the international stage. She is a member of the Indigenous Peoples of Africa Coordinating Committee, and she spoke at the Paris Climate Change Agreement signing ceremony in 2016. "I have a duty to play in this world in order to save my people," Ibrahim says. "Otherwise I have no identity."

HOW TO NAVIGATE USING THE STARS

Polynesian master voyagers don't need modern compasses to navigate their way around the vast waters of the Pacific...

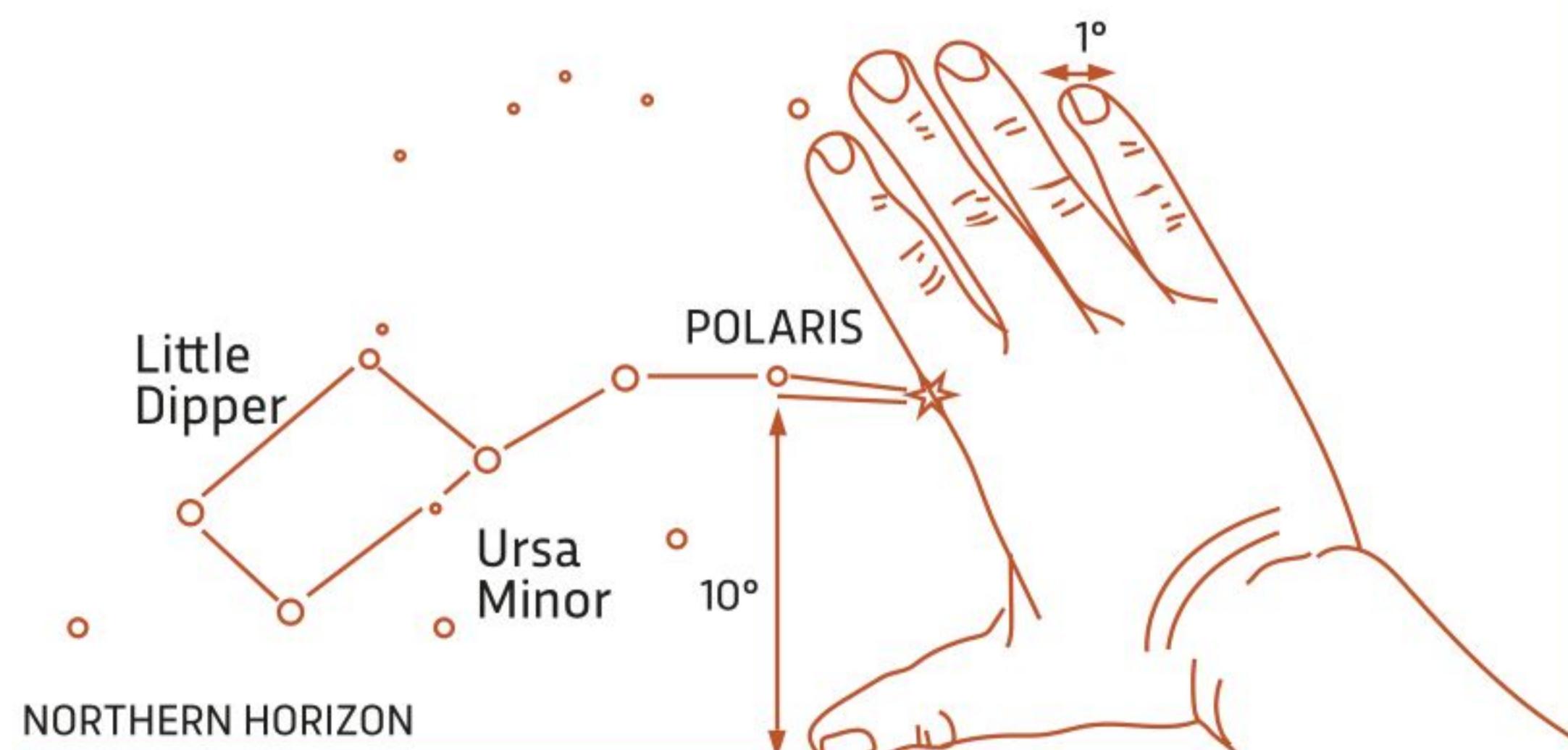
Long before the advent of modern science and technology, Polynesian navigators could travel vast distances across the Pacific between New Zealand in the southwest, Hawaii in the north and Easter Island in the southeast. Those navigational practices had almost vanished by the 1970s – but the Polynesian Voyaging Society on Hawaii has since revived the knowledge with the help of Mau Pialug, a traditional navigator from the Micronesian island of Satawal.

Kālepa Baybayan was one of a handful of Pialug's students, and he has now become a master navigator in his own right. He says a key tool is the 'star compass'. This is not a physical object but a mental construct – the navigator memorises positions of the stars in the night sky, and when they rise and set, to orientate the canoe.

The stars are useful in other ways too: the altitude of a star changes with the canoe's latitude. This means a skilled navigator with a detailed knowledge of the night sky can

pinpoint the canoe's north-south position from the height of a given star above the horizon, using an outstretched hand as a measuring tool. "You know when you are approaching land because the stars will tell you by their altitudes," says Baybayan.

The navigator also uses passing flotsam and mental arithmetic to judge how fast the boat is moving, and keeps track of the canoe's wake relative to the orientation of the canoe itself to judge the degree to which winds are driving the boat off-course. Both factors must be taken into account if the navigator is to mentally calculate the canoe's approximate east-west position. The navigator must track all of these factors – and many more – for days on end. "The trip from Hawaii to Tahiti is 2,400 nautical miles: it's going to take you about three weeks to get there," says Baybayan. "It's a mental challenge to do this without notes or writing. But it gives incredible satisfaction to complete a voyage successfully."



Hold your hand outstretched with the thumb touching the horizon. Each part of your hand measures a particular altitude (for example, the width of little finger is 1°). Here, the altitude of Polaris (the North Star) is being established



● dislikes this term because it implies the information is ancient and immutable. "It's not static, it's changing and evolving – just like my culture is evolving," she says.

In New Zealand, meanwhile, Māori iwi have long been influencing conservation policy, says Mercier. The country's iconic kauri trees are experiencing a dieback caused by a microbe that is tracked around on hikers' boots. Last year, in an effort to reduce the spread of the disease, one iwi – Te Kawerau ā Maki – placed an unofficial prohibition on people entering some of the kauri forests. "The council has just responded to say, 'we agree: let's put a complete ban there to save the trees,'" says Mercier.

TRAILBLAZERS

Indigenous knowledge even has the potential to help combat climate change, as a vast project in northern Australia demonstrates. In the final decades of the 20th Century, the West Arnhem Plateau in Northern Territory often experienced fierce wildfires at the end of the dry season, each with the potential to burn thousands of square kilometres of vegetation.

Curiously, those intense wildfires appeared to be a new phenomenon: in previous decades, when indigenous communities managed the region, devastating wildfires were rare. Those indigenous communities prevented intense wildfires by deliberately burning small areas of vegetation earlier in the dry season. At this point in the year the plants are still full of water, so fires burn less fiercely and don't destroy everything in their path. But they do create effective firebreaks that prevent disastrous wildfires at the end of the dry season.



“To be able to say, ‘no, my ancestors had this knowledge’ – it gives you pride”

Then in the late 1990s, the authorities encouraged indigenous groups to return to the West Arnhem Plateau and resume managing their land – even though modern scientists have typically looked unfavourably on the idea that land management should involve the deliberate use of fire. It turned out to be a successful move: today, intense wildfires at the end of the dry season are becoming a thing of the past once more.

“It was startlingly simple,” says Shaun Ansell, CEO at the indigenous-owned non-profit Warddeken Land Management Ltd. “The problem was there were no people in the landscape any more. The solution was to put people back.”

But that’s only part of the story. The modest fires now used to manage the landscape collectively release at least 38 per cent fewer greenhouse gas emissions than the intense wildfires that used to rage across the West Arnhem Plateau. In other words, the indigenous groups are helping fight climate change. And because the 21st-Century economy puts a price on reducing emissions, they are being paid to do so.

“The future for these people is that they should be able to run a pretty profitable business,” says

ABOVE LEFT: Polynesian navigators used the Sun, stars, waves, wind, clouds, and the movements of animals to calculate their position while sailing. There has been a resurgence in interest in learning these skills

ABOVE: Once the indigenous populations from Australia’s West Arnhem Plateau were left to manage their lands again, wildfires became less intense

Jeremy Russell-Smith, a fire ecologist at Charles Darwin University in Darwin, Australia.

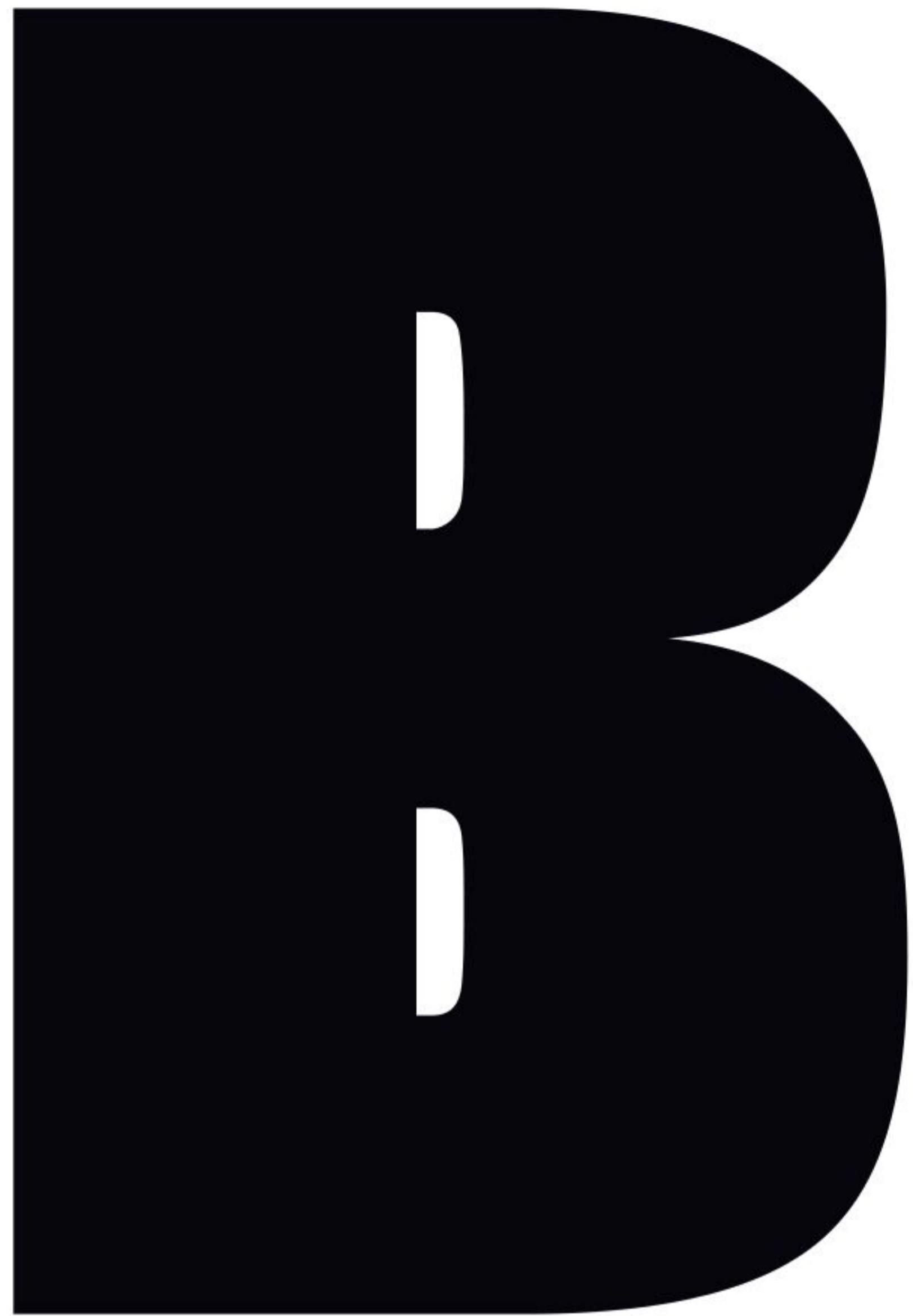
The hope is that the success of the West Arnhem Land Fire Abatement project will lead to changes in the attitudes to fire use by indigenous people elsewhere in the world, says Dr Iokiñe Rodríguez at the University of East Anglia in Norwich. Rodríguez works closely with the Pemon of Venezuela, for whom fire is an integral part of their lives and cultural identity. “Ecologists have started legitimising the Pemon’s knowledge and understanding of fire,” she says. “There’s much more acceptance of the idea that the Pemon have something to contribute.”

Noon says this idea, that indigenous knowledge has real value in the 21st-Century world, cannot be overemphasised. Modern science is benefitting from indigenous knowledge, but indigenous communities can also gain something in return. “For so long members of these communities have been told: you are lesser humans and your ancestors did nothing,” says Noon. “To be able to say, ‘no, my ancestors had this knowledge’ – it gives you pride.” **F**

Dr Colin Barras is a science writer and editor, with a background in geology, palaeobiology and palaeontology.

AUTISM



A large, bold, black letter 'B' is centered on the page. The letter is stylized with a thick, rounded font. The top left and bottom right corners of the letter are cut off, giving it a dynamic, rounded appearance. The letter is set against a plain white background.

IS FOR BIOMETRICS

Tim Webb's film *A Is For Autism* delivered a touching insight into what life is like for people with the condition. Now, a new wristwatch that scans biometric data might open another window into it

WORDS: PAUL PARSONS

even years ago, I had one of the worst conversations of my life. A paediatrician delivered the news to me and my partner that our 18-month-old son, Callum, had a severe developmental delay and was presenting symptoms consistent with autism spectrum disorder (ASD). The diagnosis of ASD was later confirmed. Callum has since attended a specialist pre-school and now goes to a special educational needs primary. His progress has been good, but his condition remains moderate to severe, and it's likely he'll require continued support into adulthood. Knowing that your child probably won't achieve independence in later life throws up unpleasant questions. What's going to happen when I'm gone? Who will care for him? Who will love him? But, as we were to find out, that wasn't the worst of it.

Autism is a lifelong developmental condition characterised by difficulties with language and social interaction, and a tendency for repetitive behaviours. The disorder often manifests itself with other mental health issues, including learning disabilities, depression and anxiety. It is a spectrum condition, meaning that its symptoms and their severity vary greatly from one individual to the next. Those who experience autism range from the high functioning, such as naturalist and television presenter Chris Packham, through to people for whom it's a profound disability, precluding the possibility of an independent life.

The US Centers for Disease Control and Prevention estimate the autism prevalence to be 1 in 59 children, with approximately five times more males being diagnosed than females. In the UK, the rate is thought to be around 1 in 100. The precise cause of autism isn't fully understood. Research points to a combination of environmental factors, such as air pollution and conditions in the womb, and genetics – although, despite many genes being implicated already, we're only just beginning to identify all of those that contribute to autism risk, and the complex interactions between them.

It has also emerged that many autistic people process sensory information differently – to the point that some sensations, loud sounds, for example, can cause pain. The frustration of not being able to communicate their predicament to



“The frustration of not being able to communicate their predicament to others, or regulate the resulting emotional distress, can lead to a meltdown”

others, or to regulate the resulting emotional distress, can lead to a state of extreme anxiety, known colloquially as a meltdown. It's not naughtiness and it's not a tantrum. It's a fight-or-flight response to a state of severe distress – the same distress you or I might experience if our lives were in danger.

EARLY WARNING SYSTEM

My partner and I have witnessed countless meltdowns, during which Callum will scream as if he were being tortured, sob uncontrollably, break anything within reach, hit and bite us, and self-harm – punching himself and banging his head into walls and floors. It's one thing when these episodes occur in the privacy of home, but when they take place in public – as they inevitably will – the consequences can be dire. There have been times when, in fury, he's almost run out into traffic. Visits to the barber's or the dentist became impossible. Pubs, restaurants – anywhere noisy and in close proximity to other people



– equally so. And then there's the spectacle of the full-on public meltdown – and the disapproving looks and the muttered remarks from those who don't understand, and who write us off as inept parents of a disobedient child. Whatever the long-term outlook, when day-to-day life becomes such an unrelenting struggle, it does drive you to the proverbial depths.

Callum was non-verbal until the age of six. He's now eight and, happily, his meltdowns have subsided somewhat as his communication skills have improved. But while they lasted, they kept us under effective house arrest much of the time. And even when we did go out it would rarely be to the shops, or the cinema, or a restaurant – but usually on a long walk, away from other people.

The thing was that we never quite knew when a meltdown was going to strike. They were often brought on by the most seemingly innocuous triggers, like the sound of a dog barking or even birds singing. Sometimes there was no obvious trigger at all. And this left us virtually incapable of doing anything to stop them.

But imagine if parents, or caregivers in general, could receive a notification to their mobile phone the instant their child's anxiety levels begin to rise. Researchers at Northeastern University, Maine Medical Centre and the University of Pittsburgh are developing just such a system. It works using a wristband, rather like a sports watch, that monitors biometric data (literally meaning 'body measurements') – specifically, the wearer's heartbeat, skin temperature, sweat levels and acceleration. The latter is important in autistic people, who often flap their arms as a way to emotionally regulate themselves (one of a group of behaviours known collectively as 'stimming').

In a study conducted in the Developmental Disorders Unit at Spring Harbor Hospital in Portland, Maine, and published earlier this year, the team fitted the wristband to 20 non-verbal autistic in-patients, aged between 6 and 17 years. Data from the bands was transmitted by Bluetooth to a server where it was timestamped and stored. Concurrently, carers kept a timestamped log of each patient's behaviour. The study generated 87 hours of data, in which the researchers observed a total of 548 aggressions – full meltdowns as well as isolated outbursts. ▶

ILLUSTRATIONS: SAM FALCONER

THE WRISTBAND REVOLUTION

The prediction of autistic meltdowns from biometric data relies on a wristband sensor called the E4 (below), manufactured by US firm Empatica. The company was co-founded by Prof Rosalind Picard, of MIT's Media Lab, whose research group developed the device as part of their own study into autistic behavioural prediction. However, they shifted their attention from autism to epilepsy after one participant in a trial happened to experience an epileptic seizure that was clearly visible in the biometric data. Empatica subsequently developed the Embrace, a wristband plus smartphone app that can monitor for the occurrence of potentially life-threatening 'grand mal' seizures. "Every one of the grand mal seizures was having these responses that we could pick up on the wrist," says Prof Picard.



“The hope is that all this extra data will assist in understanding how an autistic person’s immediate environment can exacerbate their condition”

● The researchers chopped this data up into intervals, each 15 seconds in length. For each interval they calculated summary statistics – the average, minimum, maximum and the variability within the interval – for each of the biomarkers that the wristband records. Finally, they added a label – essentially a yes/no indicator – from the carers’ notes, to show whether or not there was a meltdown episode in each interval.

Next, they looked for patterns in the biometric marker data that presaged the onset of the aggressive episodes recorded by the labels. They did this by crunching the processed numbers through a machine learning algorithm – a piece of computer software that uses statistical methods to extract knowledge and insights from an abstract mass of data. In this case, it was trying to construct a model that could forecast whether or not a meltdown was going to occur in any given 15-second interval, based on the biometric readings in the preceding intervals. In fact, they built a number of different models – a person-dependent

model for each patient, using just that individual’s data, plus one ‘global’ model pooling together the data from everyone.

“If we used three minutes of past data, that gave us the highest accuracy of prediction one minute into the future,” says team member Prof Matthew Goodwin, of Northeastern University. “For the global model, that accuracy was 71 per cent. Out of every 10 times that you would make a prediction that an aggression is going to happen in the next minute, then roughly seven times it will come to that.”

Of course, that also means that 3 times in 10 it’ll be a false alarm. However, Goodwin says that clinicians – and, indeed, most parents – would rather deal with these ‘false positives’ than for genuine meltdowns to go undetected. “They would rather have their attention triaged and nothing occurs than have a false belief that they don’t have to attend and something does.” He also believes there’s room to improve the model’s accuracy, both in the way the data is pre-processed and by employing more sophisticated machine learning algorithms. And this work is ongoing. Already, for the person-dependent model, the accuracy is higher, averaging around 84 per cent.

Goodwin and his team are about to trial the technology at a residential care facility for autistic people in the UK. The charity Autism Together operates the Raby Hall care home in the Wirral. From July they’ll be trialling biometric wristbands on a group of residents, the first time the technology has been applied in a residential care setting. But it won’t just be biometric systems on test. Goodwin’s team will also be installing video and audio monitoring equipment, as well as devices to record light levels, ambient temperature, humidity and barometric pressure.

The hope is that all this extra data will permit not just prediction of meltdowns, but also assist in understanding how an autistic person’s immediate environment can exacerbate their condition. And that could help architects design new residential homes tailored to people on the autistic spectrum, and to consider the needs of the autistic individual when designing other buildings, such as shops, cinemas and restaurants.

AUTISM MYTHS: DON’T BELIEVE EVERYTHING YOU HEAR

All autistic people are geniuses

No. While autism can be a gift to higher functioning individuals – improving their ability in subjects such as mathematics and software – it is not true to say that everyone with the condition is a genius. Studies have shown that around half of autistic children also have a learning disability (defined as an IQ below 70), while an estimated 25 to 50 per cent never develop fluent spoken language, limiting their educational options.

Vaccines cause autism

Wrong again. The notion that vaccines cause autism originates from a now discredited 1998 paper by British former doctor Andrew Wakefield, claiming to link the disorder to the MMR vaccination for measles, mumps and rubella. An investigation by *The Sunday Times* revealed Wakefield had manipulated his data and had received money from solicitors seeking evidence against vaccine manufacturers.

Autistic people have no empathy

Autistic people struggle with social interaction – they can find it hard to read other people’s emotions and, as they tend to process information more slowly, can have trouble maintaining a conversation. It can make them seem shy or aloof, but they’re not antisocial or lacking in empathy. The same applies to claims that they lack a sense of humour. My son laughs as much as any child – his general happiness is probably what keeps me going.



Goodwin imagines that, in the coming years, this technology may combine with the Internet of Things to enable automated safeguards in the care of those on the autism spectrum. “Somebody starts to escalate physiologically,” says Goodwin. “Might the lights in the room automatically dim down? Might some quiet music come up?” With so many people now receiving autism diagnoses, the demand for care is increasing – automated solutions such as this could help triage the attention of human carers more effectively.

STATES OF MIND

The technology also represents a potential sea change in how we measure someone’s emotional state generally. Other aspects of health and development can be determined quantitatively – by, for example, a brain scan, an X-ray or a genetic test. But assessing behaviour, mood or overall state of mind, is comparatively imprecise. It might, for example, involve them filling out a questionnaire, the answers to which are naturally subjective. And even if you could put patients in some kind of laboratory-based ‘behaviour scanner’, obtaining an accurate picture in such an unnatural and potentially stressful environment seems unlikely.

Biometrics, on the other hand, offers an unobtrusive window to look inside a patient and quantify these nebulous aspects of human health objectively, in a way never before possible. And for people on the autism spectrum – who are often intellectually impaired, or who may lack the language skills necessary to express how they’re feeling – the benefits could be even more profound. “These are the folks that we understand the least,” says Goodwin. “These are the folks that we need to support the most.” **F**

Dr Paul Parsons is a science writer and data analyst based in Buckinghamshire. He tweets from [@NasaProPlus](#). His latest book, *The Beginning And The End Of Everything* (£16.99, Michael O’Mara Books), is out in November.

FURTHER INFORMATION

AUTISM TOGETHER

The charity collaborating on the biometric wristband prediction research, Autism Together is raising money to build a world-leading assessment and diagnostic centre in the Wirral. Donate and find out more here: bit.ly/autism_together

THE NATIONAL AUTISTIC SOCIETY

Support and information for autistic people across the UK is provided by the National Autistic Society. The society also operates a number of specialist schools throughout the country. More information here: bit.ly/autistic_society

SEEKING DIAGNOSIS

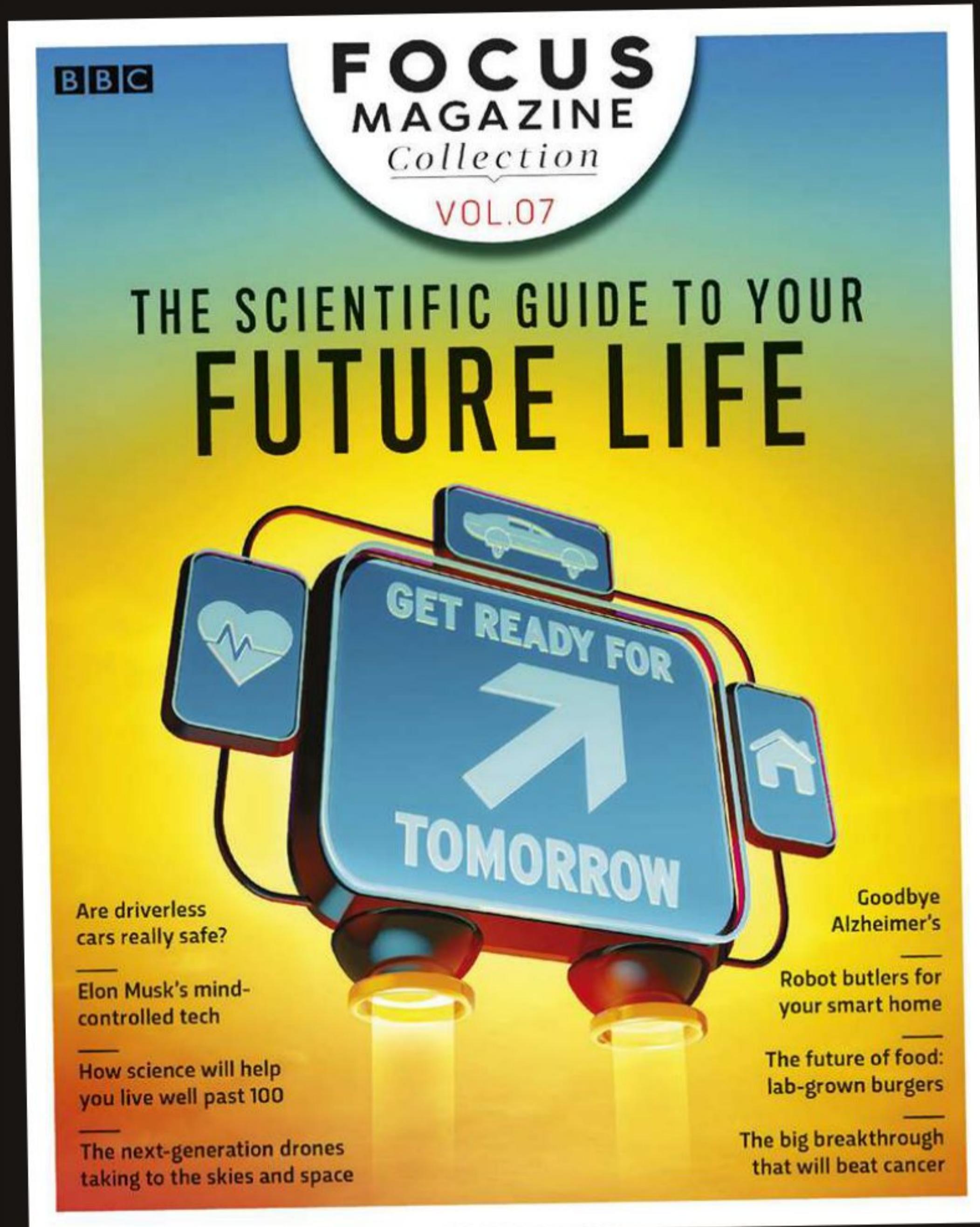
If you suspect your child may be autistic, the best treatment is early intervention. The UK charity Ambitious About Autism has a guide to the signs to look out for: bit.ly/autism_signs. And information on obtaining a diagnosis: bit.ly/autism_diagnose

A IS FOR AUTISM

Tim Webb’s award-winning short film from 1992, *A Is For Autism*, features interviews, drawings, music and animations all contributed by people on the autism spectrum. It remains one of the most poignant insights into the autistic world. bit.ly/a_is_for_autism

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Q & A



YOUR QUESTIONS ANSWERED

AUGUST 2018

EDITED BY JAMES LLOYD



Would seagulls exist without humans?

DAN JONES, SOUTHAMPTON

The gulls we most commonly see in our UK towns are herring gulls. Since the 1960s they have increasingly been migrating inland, away from their coastal habitats, to live and feed: this is largely due to overfishing and the rising sea temperatures associated with climate change (as fish are being forced to greater depths to feed on

plankton). The gulls scavenge in landfill sites and are drawn to areas where we feed them. Although often seen as a nuisance, some species of seagulls are now endangered. Without humans, their natural food supply would recover so, on balance, they would be much better off without us. **cc**



Could a pH greater than 14 exist?

ADAM KING, HUDDERSFIELD

The pH scale typically stretches from zero to 14, passing through a neutral pH7 (freshly distilled water). Strong acids have a low pH, while alkaline chemicals, such as bleach and liquid drain cleaner, have a high pH.

The scale was invented in 1909 by a Danish biochemist called Søren Sørensen. It describes how many hydrogen ions (protons) are present in a solution: the higher the pH, the lower the hydrogen ion concentration, and vice versa. But the scale does not have fixed limits, so it is indeed possible to have a pH above 14 or below zero. For example, concentrated hydrochloric acid can have a pH of around -1, while sodium hydroxide solution can have a pH as high as 15. **ED**

IN NUMBERS

12,000

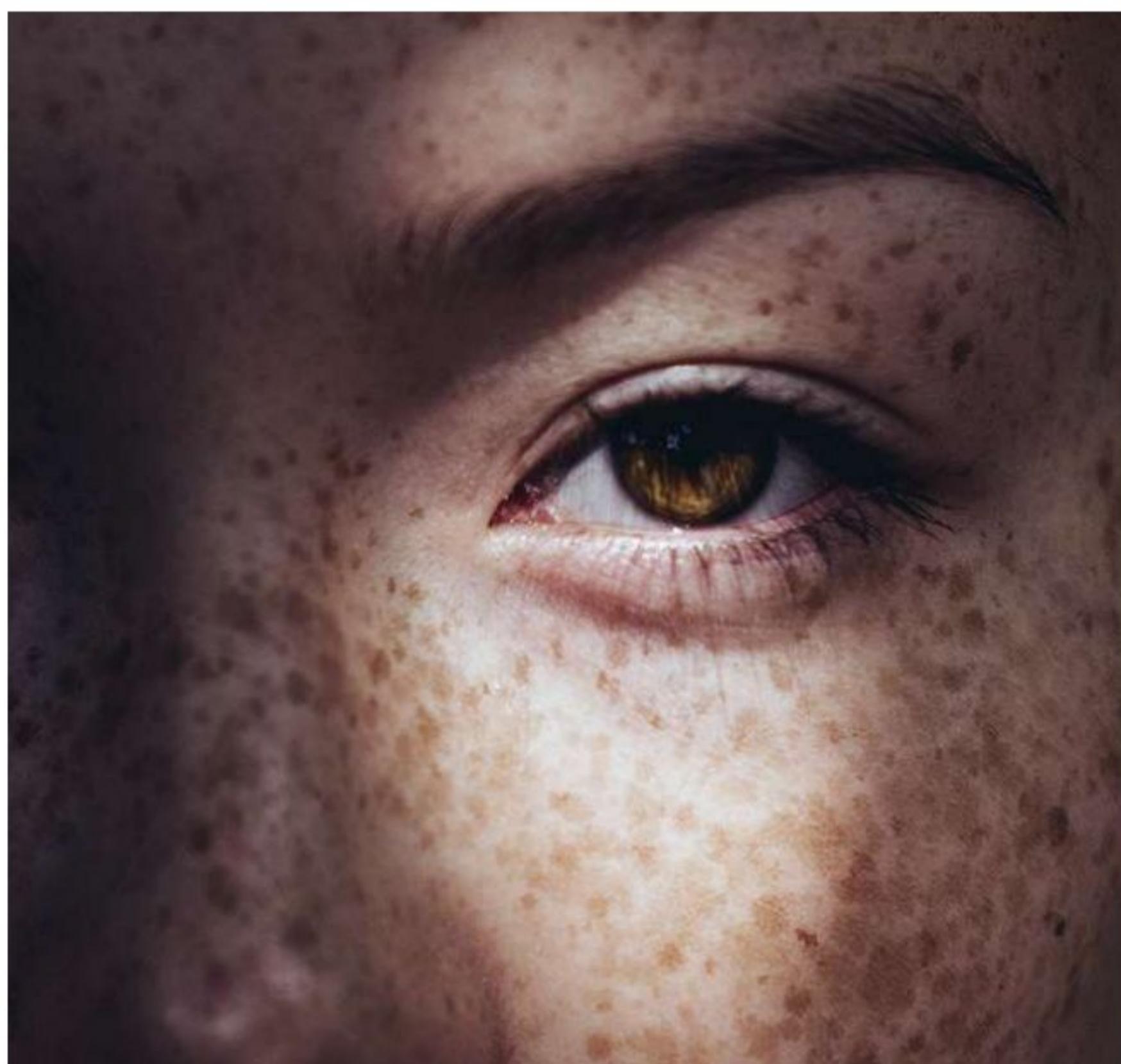
The distance, in kilometres, that some painted lady butterflies migrate annually. This knocks monarchs, with their migration of 4,800km, off the top spot.

100

The mass, in kilograms, of the UK-built RemoveDebris satellite. It's the largest satellite ever launched from the ISS and will trial methods to remove space junk.

9,000

The approximate number of years ago that domestic dogs first arrived in North America. Genetic evidence suggests they travelled with humans from Siberia, via a land bridge.



Why do some people get freckles when it's sunny?

SAMANTHA GOODWIN, LIVERPOOL

When your skin is exposed to UVB radiation in sunlight, specialised cells called melanocytes produce the dark pigment melanin to protect the skin. Usually this melanin is produced evenly and results in a tan, but some gene variants, such as the MC1R gene that results in red hair, cause the melanocytes to overproduce melanin granules. This creates little pigment clusters that get darker in sunlight. **LV**

WHAT CONNECTS...

...ONE FLECK OF PAINT AND THE PILLARS OF CREATION?

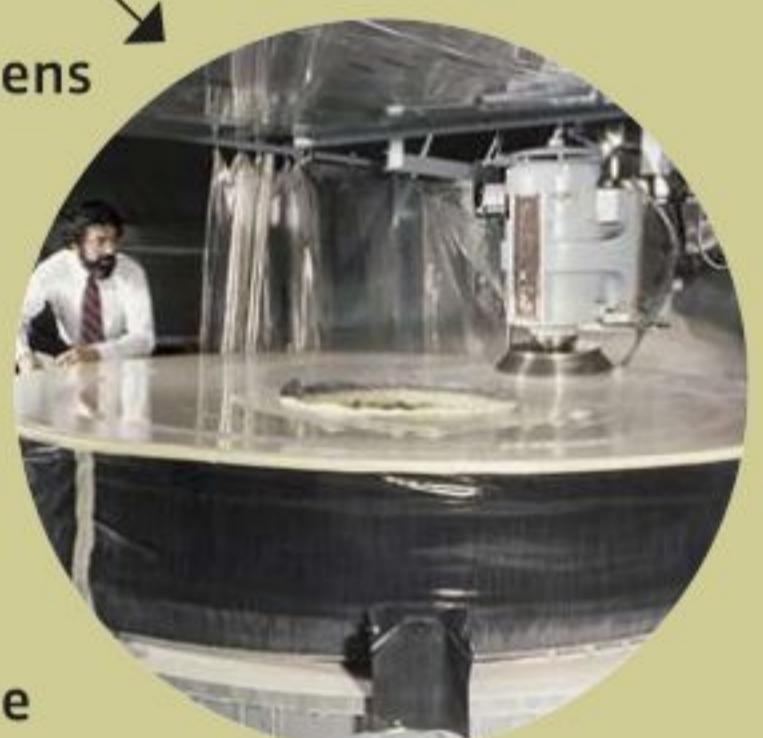
1.



The *Pillars of Creation* is one of the most iconic images from the Hubble Space Telescope. But when the telescope was launched in 1990, a manufacturing defect meant it had blurred vision.

2.

Although the Hubble's mirror lens was the most precisely manufactured optical mirror ever made, it had been polished using a calibration device that was out by 1.3mm.



3.



To fix this, the Space Shuttle Endeavour took a special corrective lens up to Hubble, where it was fitted over the course of five separate spacewalks – the most of any Space Shuttle mission.

4.

The fault was eventually traced to a chip in the paintwork inside the calibration device. This exposed a tiny bit of shiny metal that reflected just enough light to distort the measurements. The improved image can be seen here.



The A, B, O and AB blood types are dictated by the presence or absence of particular substances on the red blood cells

Is there any truth in the blood type diet?

CHARLOTTE MCGUINNESS, LONDON

In 1996, a naturopath named Peter D'Adamo argued that eating a diet 'designed' for your blood type (O, A, B, or AB) meant that your body would digest food more efficiently, and you would lose weight and prevent disease. The diet has proven immensely popular, with millions of followers. Blood is indeed involved in digestion: the digestive process occurs in the gut, and the nutrients are absorbed and transported by blood to the various cells and organs. There is, however, zero evidence that the different macronutrients (glucose, amino acids and fatty acids) react to the four blood types in any appreciably different way. Our individual biology may well influence how we respond to food, but not our blood type. There is no truth to this diet. **GY**



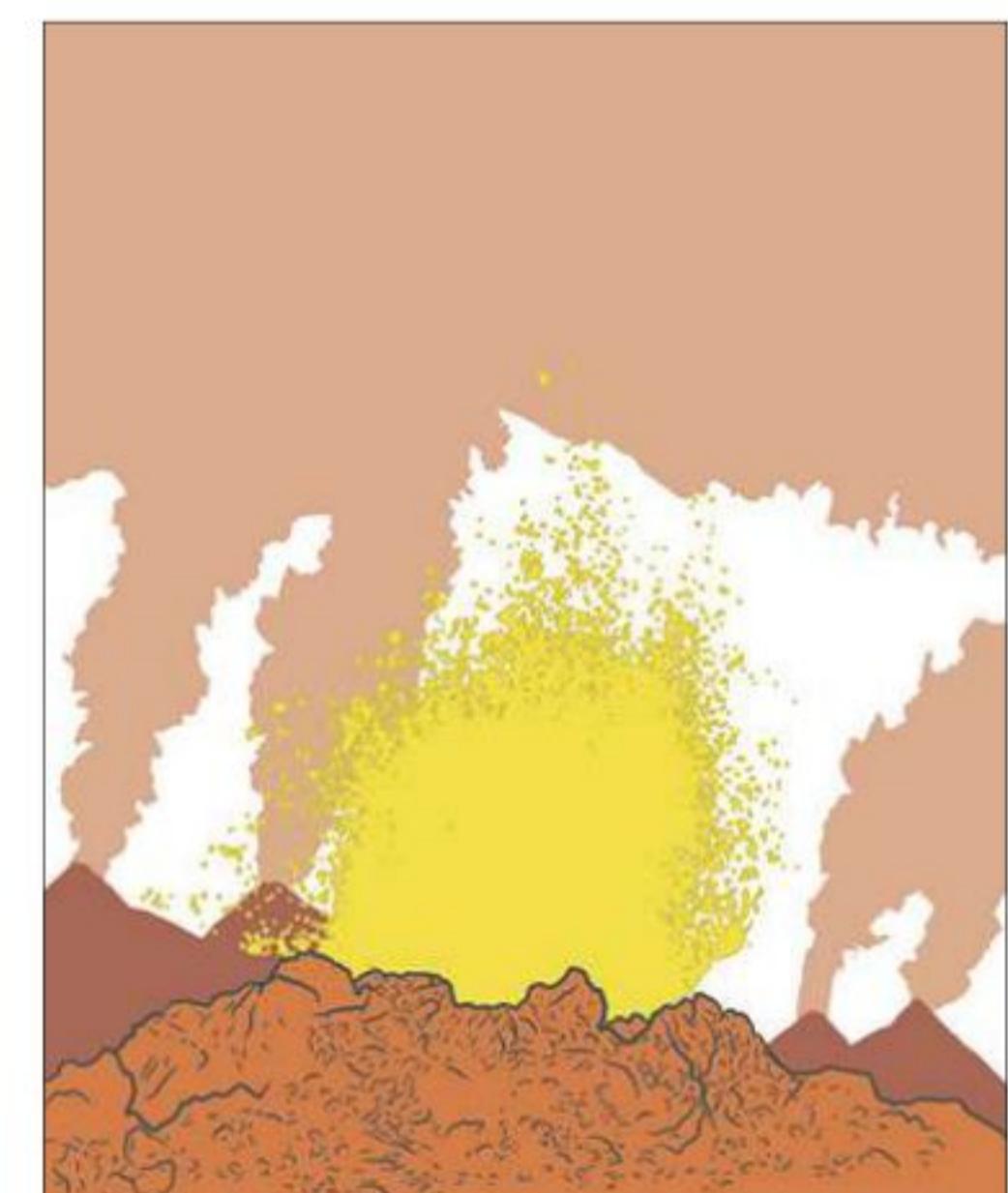
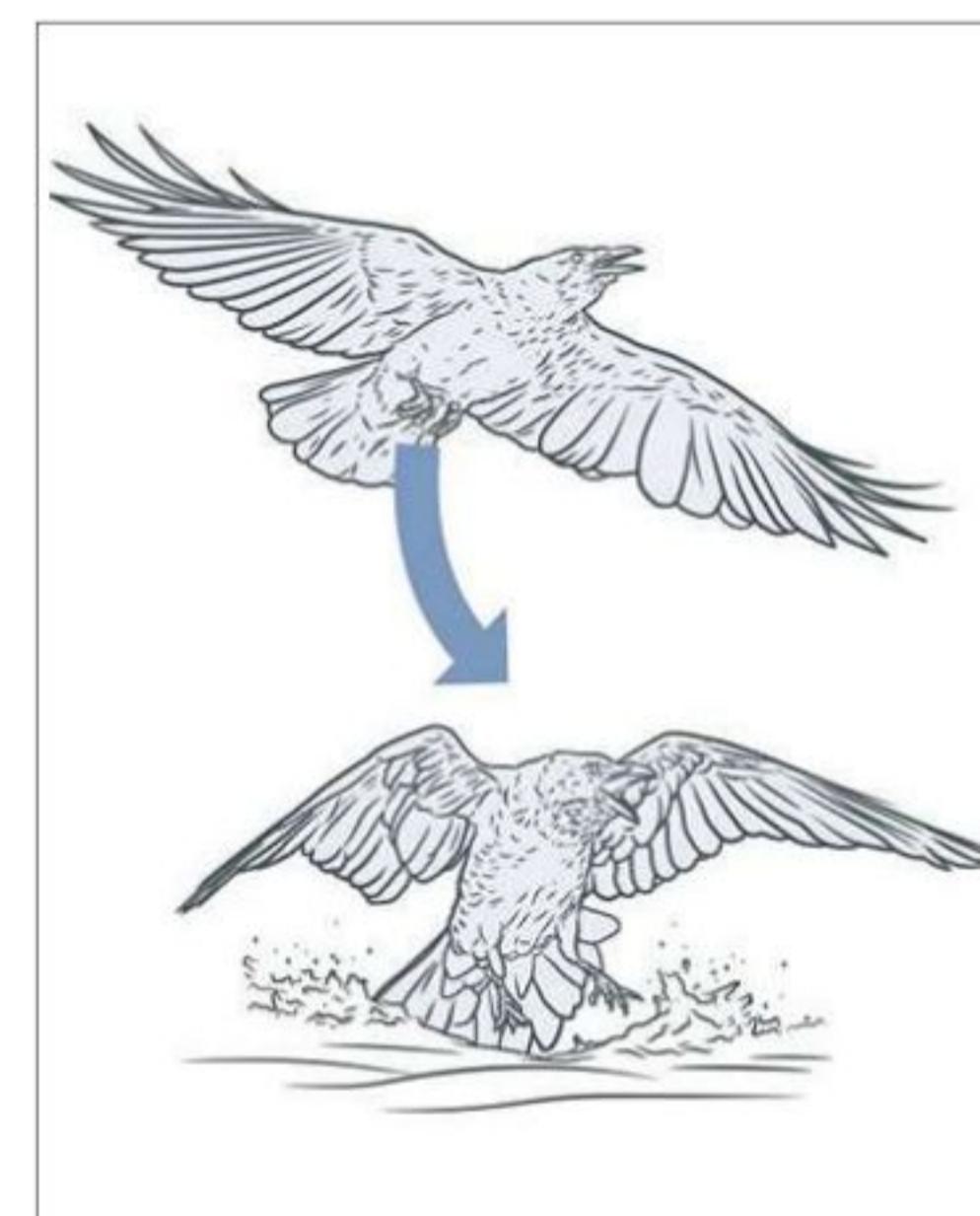
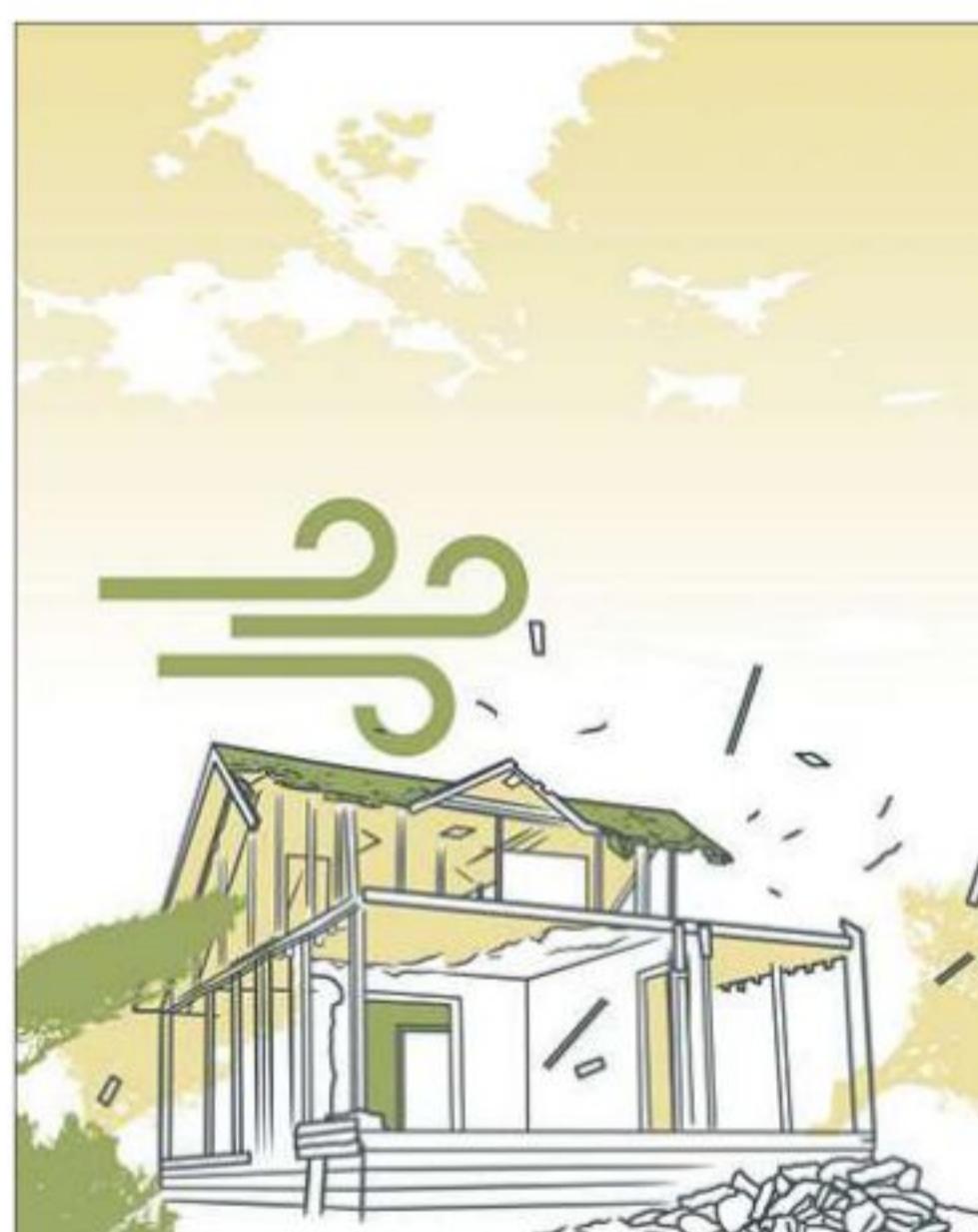
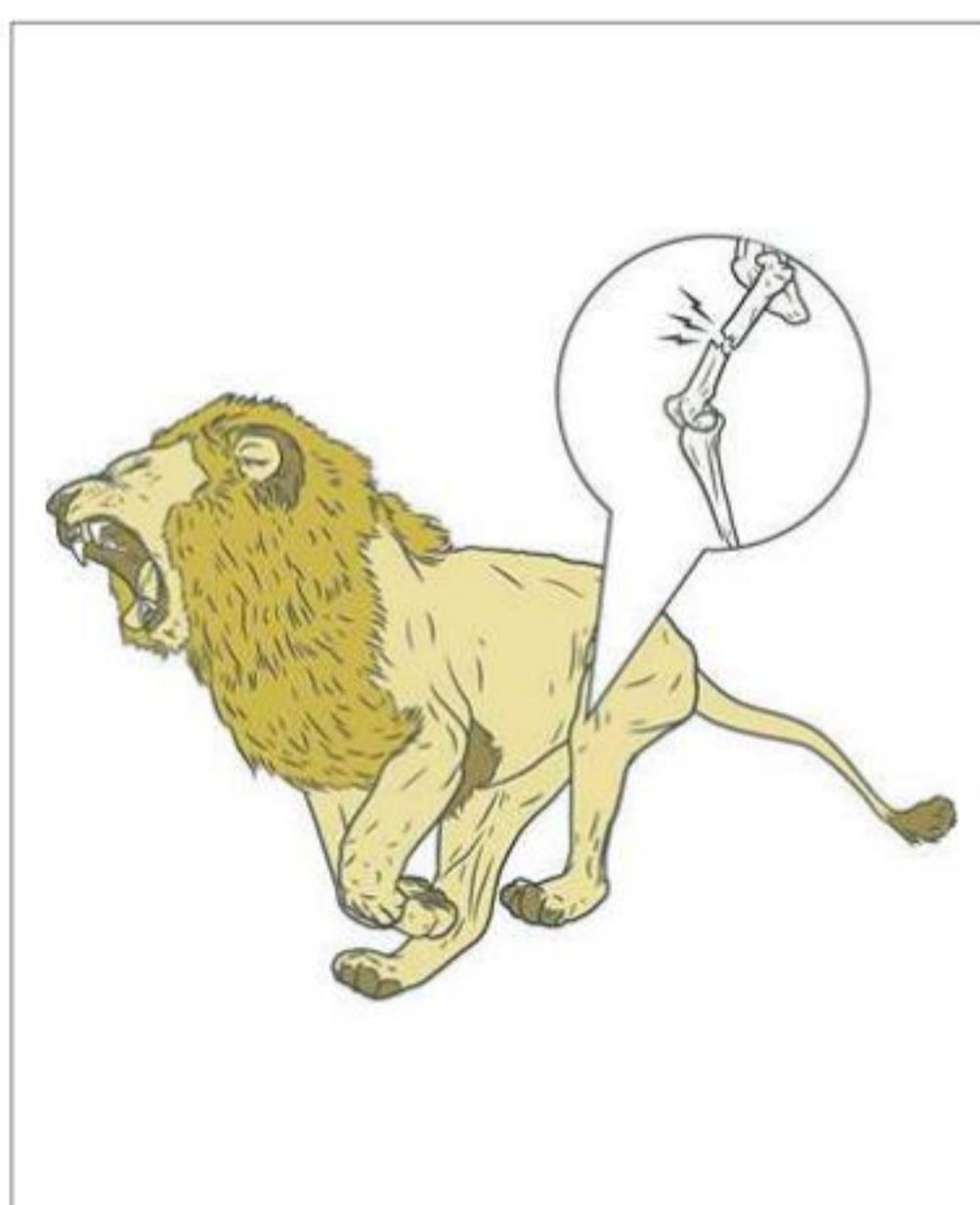
Why do dogs tilt their head when you speak to them?

TOBY GRAHAM, SHREWSBURY

A dog's range of hearing is wider than ours but not as accurate. Perking their ears up while tilting their heads helps them pinpoint where noises are coming from more quickly. It also helps them to hear and interpret the tone of our voices, and pick out familiar words such as 'walkies'. Dog behaviour expert Dr Stanley Coren believes that dogs with shorter muzzles tilt their heads less because they have a better view of our facial expressions and are therefore not so reliant on their ears to understand us. **CC**

THE THOUGHT EXPERIMENT

WHAT IF THE EARTH DOUBLED IN SIZE?



1. GRAVITY

If we assume that the density of the Earth stays the same, then doubling the radius increases the planet's mass eight-fold. Surface gravity is now doubled, so most plants and trees promptly fall over. Any animal dog-sized or bigger can't run without breaking a leg, so large predators can't move fast enough to catch prey.

2. DAY LENGTH

Angular momentum is proportional to mass x radius squared. As angular momentum is conserved, the planet now rotates 32 times slower. A day lasts over a month! This creates huge temperature imbalances between the light and dark side of the planet, powering wind storms that flatten all buildings.

3. AIR PRESSURE

If the atmosphere doubles in size too, then air pressure is doubled. This is still breathable and the extra oxygen helps to offset the greater effort needed to pump blood up to your brain. The thicker air actually makes flying easier for birds, although most need to land on water to cushion the impact caused by the stronger gravity.

4. PLATE TECTONICS

The greater volume of radioactive elements in the mantle means hotter magma. Even though the crust is thicker, hundreds of new volcanoes erupt, pumping more CO₂ into the atmosphere and creating a runaway greenhouse effect. This leads to the biggest extinction event Earth has ever seen.



Can a DNA test differentiate between a person's father and brother?

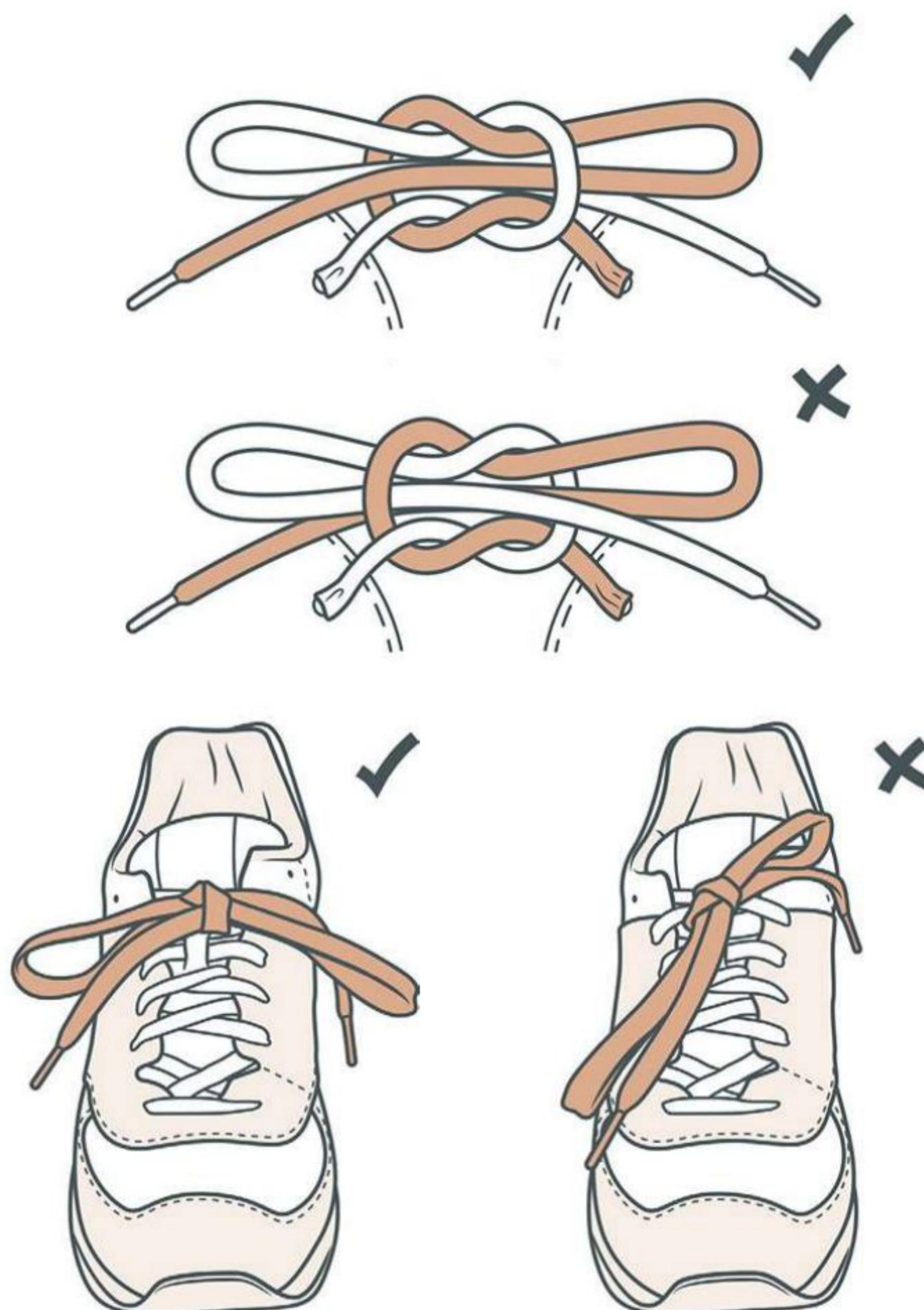
SOFIA, MANCHESTER

Yes. You inherit exactly half of your father's genes, so checking 16 genetic markers on both of you is enough to be 99.99 per cent confident that someone is your father. Brothers also share half their genes with their other siblings, but only on average – the exact relatedness varies. By comparing lots more genetic markers, a DNA test can show that two siblings are very closely related but can't be father and son (or father and daughter) because the genetic relatedness isn't exactly 50 per cent. **tw**

Is there a way to tie shoelaces to stop them coming undone?

SAUL PARSONS, LEICESTER

The ability of shoelaces to work themselves free is one of life's little irritations. But as a team at the University of California, Berkeley, showed last year, it's actually the result of some surprisingly strong forces. The repeated impact of our shoes on the floor generates forces of up to seven times that of gravity, which loosen the knot. Then the swinging motion of our legs creates swishing forces that cause the laces to slide apart. The team found that one way to reduce this is using a so-called square knot: first cross the laces and thread one under the other as normal, but then form the bow by crossing and threading the laces in the opposite direction. **RM**



How have some plants evolved to mimic insects when they don't have vision?

ANDREW SETCHFIELD, SHEFFIELD

The bee orchid has flowers that look like the females of a particular species of bee. When male bees are tricked into mating with them, they get covered in pollen and spread it from flower to flower. Clever as this seems, the bee orchid is oblivious. It can't see itself or the bee and doesn't have the nervous system needed to appreciate the similarity anyway. Luckily, it doesn't need to. Evolution isn't steered by individuals. It just throws a lot of spaghetti at the walls and sees what sticks. The ancestor of the bee orchid probably relied on nectar to lure bees, just like other flowers. But then a random mutation happened to make one strain look slightly more inviting to bees than the other flowers. Over time, the flowers that looked most like female bees attracted more pollinators, even when they didn't bother producing much nectar. So they reproduced quicker with less effort. This is a slow process, but with a few million years and enough determined bees, you can get a lot done. Although to be fair, it still only looks vaguely like a bee, so it's a good thing that bees don't have great eyesight either! **tw**





Bee orchids, found across Europe, the Middle East and North Africa, tempt male bees to visit them by resembling a female bee. Can you see the similarity?

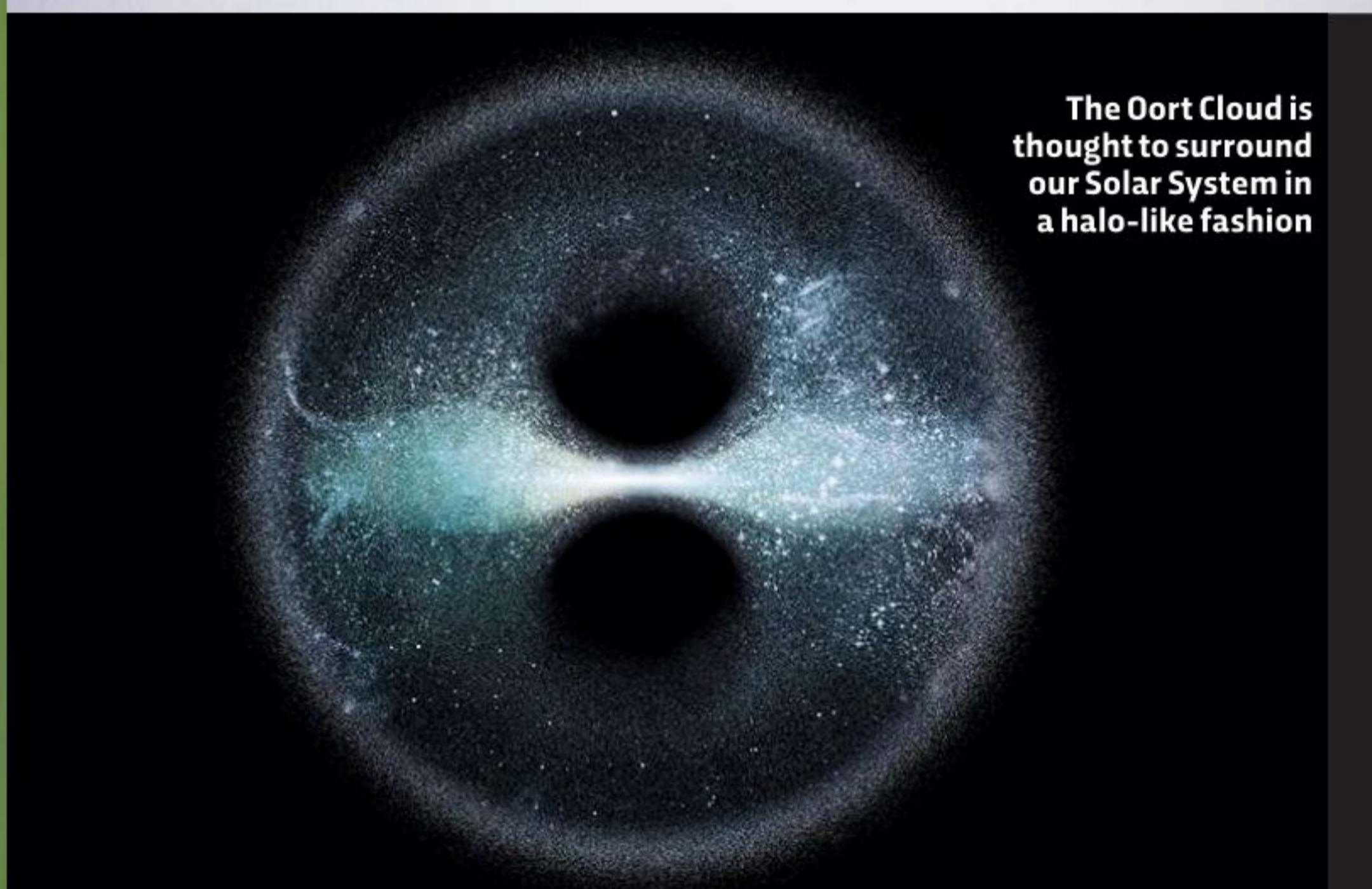
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Has our sense of smell evolved based on what is good and bad for us?

TOM RUSSELL, DEMOCRATIC REPUBLIC OF THE CONGO

Yes, we have evolved a higher sensitivity to smells that indicate poison or danger. Rotten fish, for example, smells so disgusting because it's teeming with bacteria, and we've evolved to interpret the odour as a warning that eating the fish would likely make us ill. It's true that we become more sensitive to some smells after we learn to associate them with a bad experience. But cadaverine and putrescine, which are produced by decaying corpses, smell revolting even if you have never smelled a dead body before. This aversion is shared with lots of animals and evolved at least 420 million years ago. **LW**



The Oort Cloud is thought to surround our Solar System in a halo-like fashion

Has any other star come close to our Solar System?

DAVE WHITE, PORTLAND, USA

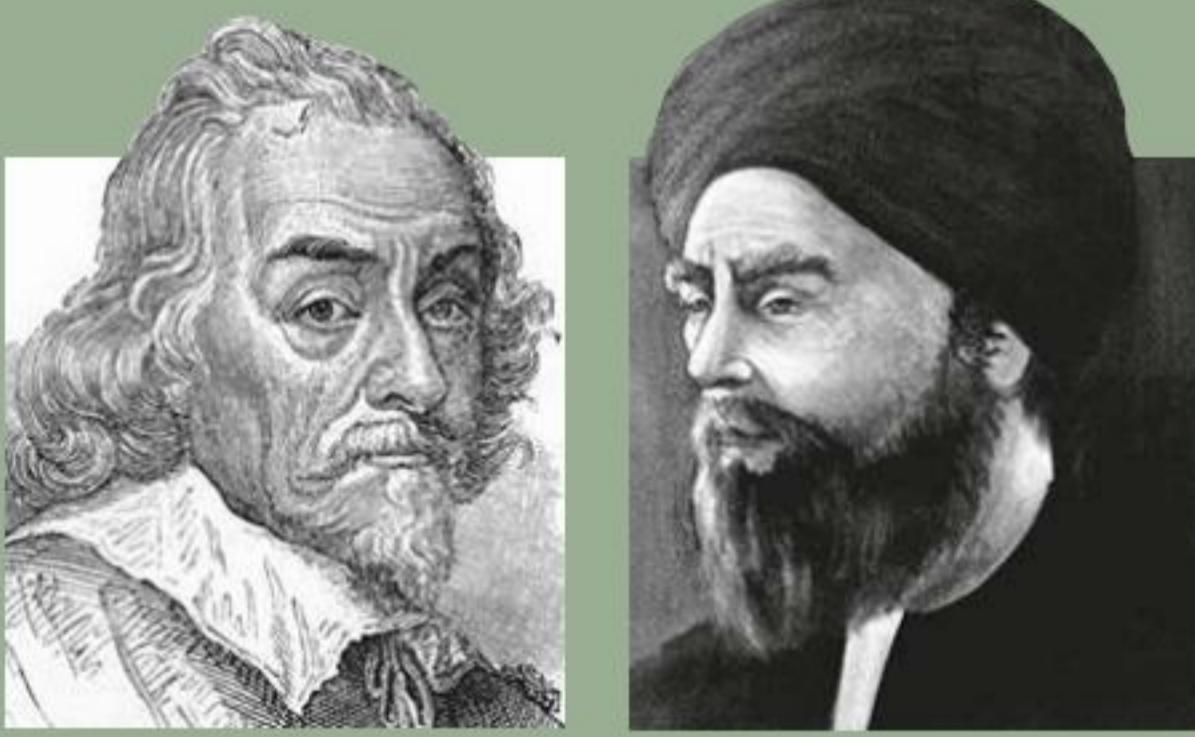
Unlike planets, stars seem fixed in the night sky. Yet in reality, they too are moving through space: their vast distance means it just takes a long time for their movement to become obvious. Over the long history of the Solar System, countless stars have approached our planetary neighbourhood. While there's no evidence of a direct collision, the orbits of the outer planets are thought to have changed dramatically during the early history of the Solar System. It's possible that this was due to gravitational jostling among the planets themselves, but a stellar intruder can't be ruled out.

Even a 'near miss' could have devastating consequences. Far beyond the known planets lies a vast collection of icy debris and comets surrounding the Sun known as the Oort Cloud. A star passing even a light-year or so away from us could stir these up, hurling cosmic missiles at the planets.

To assess the risk, astronomers at the Max Planck Institute for Astronomy, Germany, recently published an analysis of the movement of over seven million stars. Fortunately, they found just one – codenamed Gliese 710 – likely to disturb the Oort Cloud over the next million years or so. **RM**

WHO REALLY DISCOVERED?

HOW BLOOD CIRCULATES



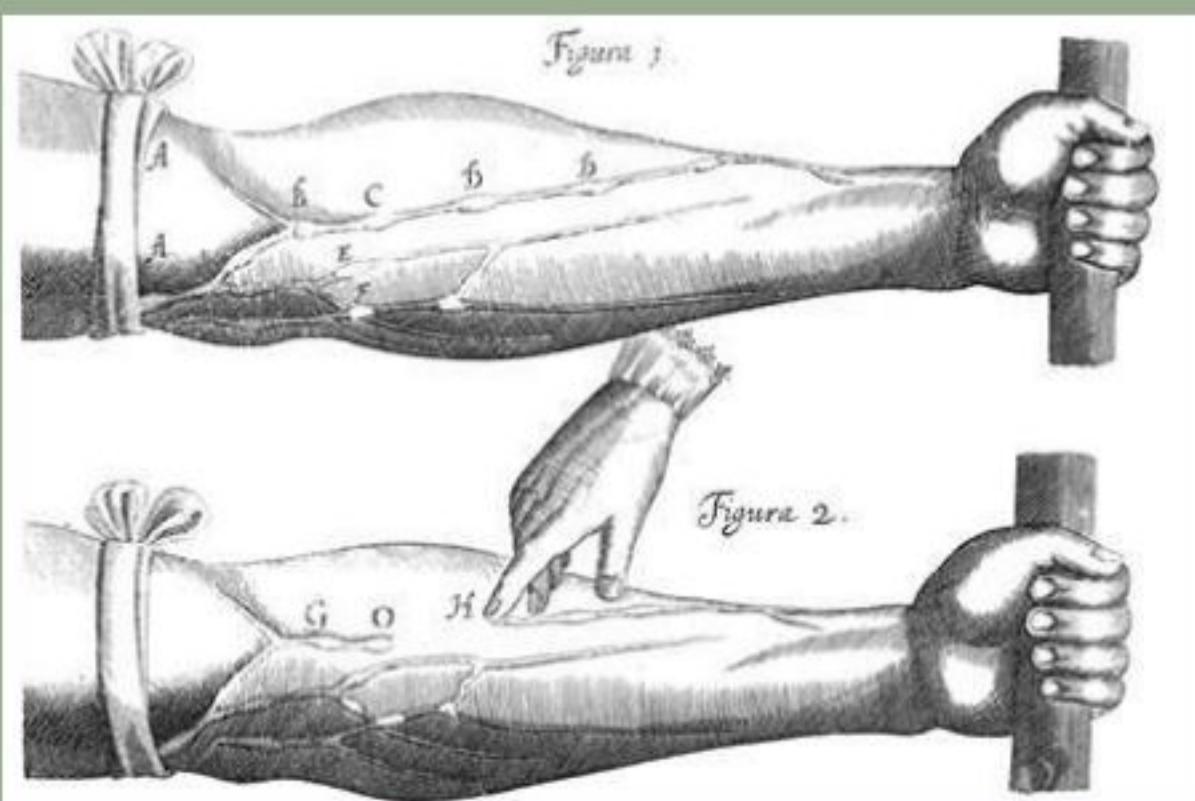
WILLIAM HARVEY

IBN AL-NAFIS

In 1628, the English physician William Harvey created a sensation by publishing a radical new view of how the body uses blood. Until then, doctors had relied on the 1,300-year-old teachings of Galen, a Greek physician, who claimed that blood was created by the liver and then consumed by living tissue. In contrast, Harvey argued that the amount of blood is fixed, and constantly circulates round the body, being refreshed by passing through the lungs and other organs.

Harvey's revolutionary view implied that blood supply was limited – casting grave doubt over widely-used practices such as 'blood-letting'. After sometimes bitter criticism, Harvey's claims were confirmed and he is now regarded as one of the founders of modern medicine.

But historians have since found that Harvey's revolutionary ideas about the circulation of the blood had already been discovered over 400 years earlier. The 13th-Century Arab physician Ibn al-Nafis showed that the construction of the heart contradicted Galen's claims, and argued that there must be tiny blood vessels allowing blood to circulate. Now called capillaries, their existence was confirmed only in the 17th Century. Unfortunately for al-Nafis – and countless patients – his pioneering work remained unknown in Western Europe until the early 20th Century. RM



Could dynamos be installed in the wheels of an electric car to provide a perpetual source of power?

AYYAPPAN PERUMALSAMY, CHENNAI, INDIA



When braking, Formula One cars store energy, which is later used for a speed boost

We already recover power from the wheels of some cars when slowing. Kinetic energy recovery systems (KERS) have been used in Formula One racing to store energy in a flywheel when braking, and then push it back to the wheels later for a boost in speed. Electric cars often use regenerative braking, which converts the speed of the wheels into electrical power to recharge the battery. These systems are a great way to increase efficiency, but like everything in the Universe, they are not 100 per cent efficient. Sadly, the laws of physics prohibit the existence of true perpetual motion, so it's the best we can do. PB

Does dreaming affect the quality of our sleep?

ASHLEY MARTIN, HAMPSHIRE

There's research to suggest that having frequent nightmares is associated with poorer subjective sleep quality. Nightmares can cause anxiety, making it more difficult to fall back to sleep, or nod off in the first place. However, the link between dreaming and sleep quality goes both ways. We are more likely to remember a dream when we're woken from it, so if we sleep badly and have multiple wakings during the night, we may be more likely to recall the content of our dreams. AG





WHAT IS THIS?

Corridor on a cliff

Perched on China's Fuxi Mountain in Xinmi, Henan Province, is this U-shaped glass skywalk. By peering through the transparent floor, visitors can enjoy dizzying views of the valley bottom, located a whopping 360 metres beneath their feet. In recent years, China has developed something of a reputation for building terrifying glass bridges that appeal to daredevil tourists, and is boasting this latest one is a record-breaker. Incredibly, Guinness World Records receives 2,000 applications from China a year, so it remains to be seen if this one earns a coveted place in the book.

CAN ANIMAL SENSES TAKE US BEYOND HUMAN LIMITS?

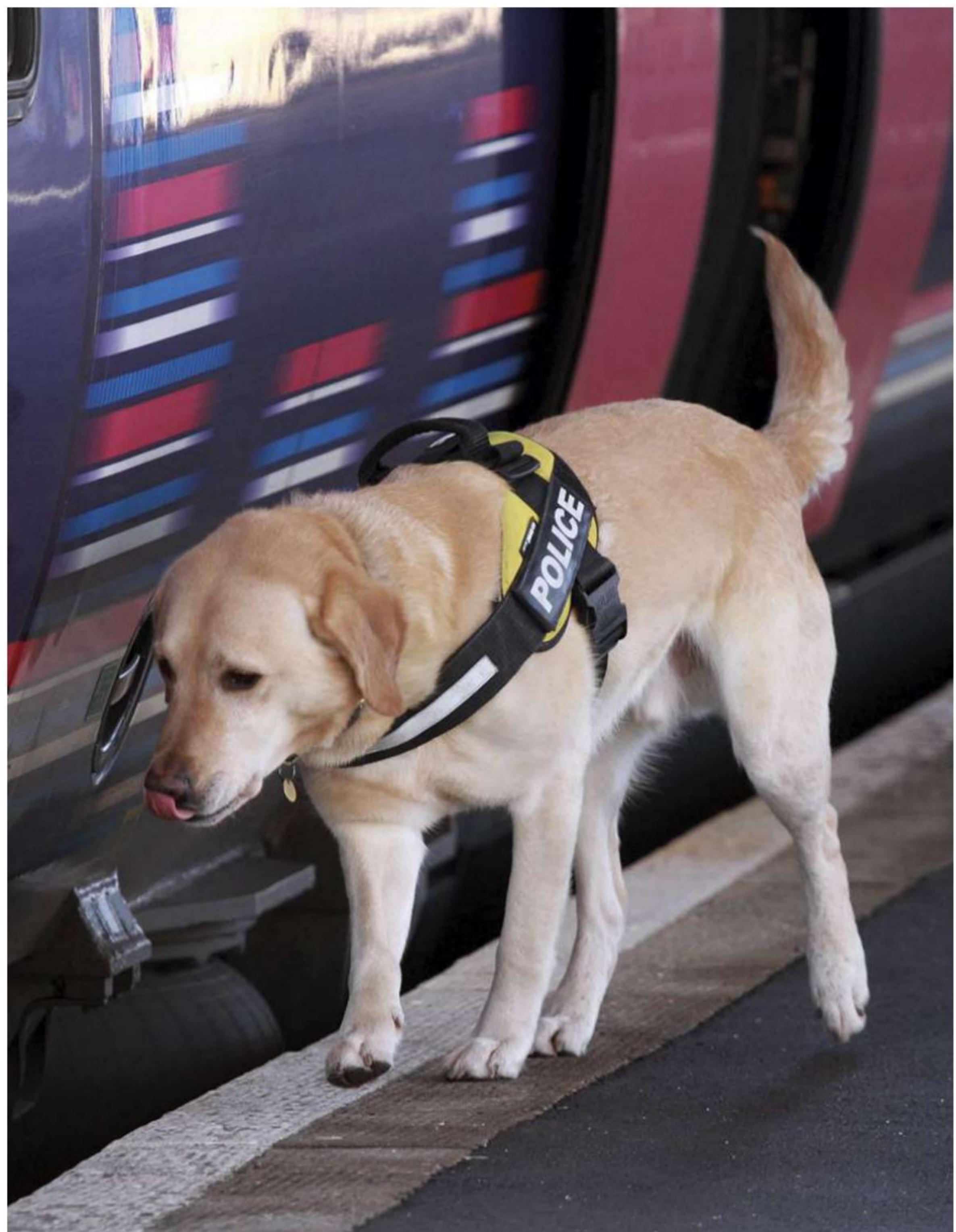
We teamed up with the folks behind BBC World Service's *CrowdScience* to answer your questions on one topic. You can tune in to *CrowdScience* every Friday evening on BBC World Service, or catch up online at bbcworldservice.com/crowdscience

How can we harness animal senses?

Humans have been using animals' senses for thousands of years. Dogs are a great example: we've used their sharp sense of smell to help us hunt and, more recently, to help police locate drugs or explosives, and even to detect the presence of certain illnesses, like tuberculosis or cancer. Marine mammals have also been valuable, but in a different way: instead of utilising their behaviour directly, we've been inspired by their echolocating clicks. In 2010, scientists at the University of Southampton developed a new kind of sonar that works in shallow waters, based on dolphins' ultrasonic signals.

Could we use insect senses too?

'Sniffer bees' may soon become a thing! Bees are currently being trained to detect various odours by a team at the University of Konstanz in Germany. For example, by exposing the bees to particular odours and rewarding them with sugar water, the bees can be trained to detect explosives used in land mines. The idea is that bees released into a land mine area would fly towards the mines, revealing the mines' location without setting them off. The same team has also bred a strain of fruit fly whose antennae light up in different patterns when they smell cancer cells. It's hoped that the research will lead to new kinds of medical screening techniques.

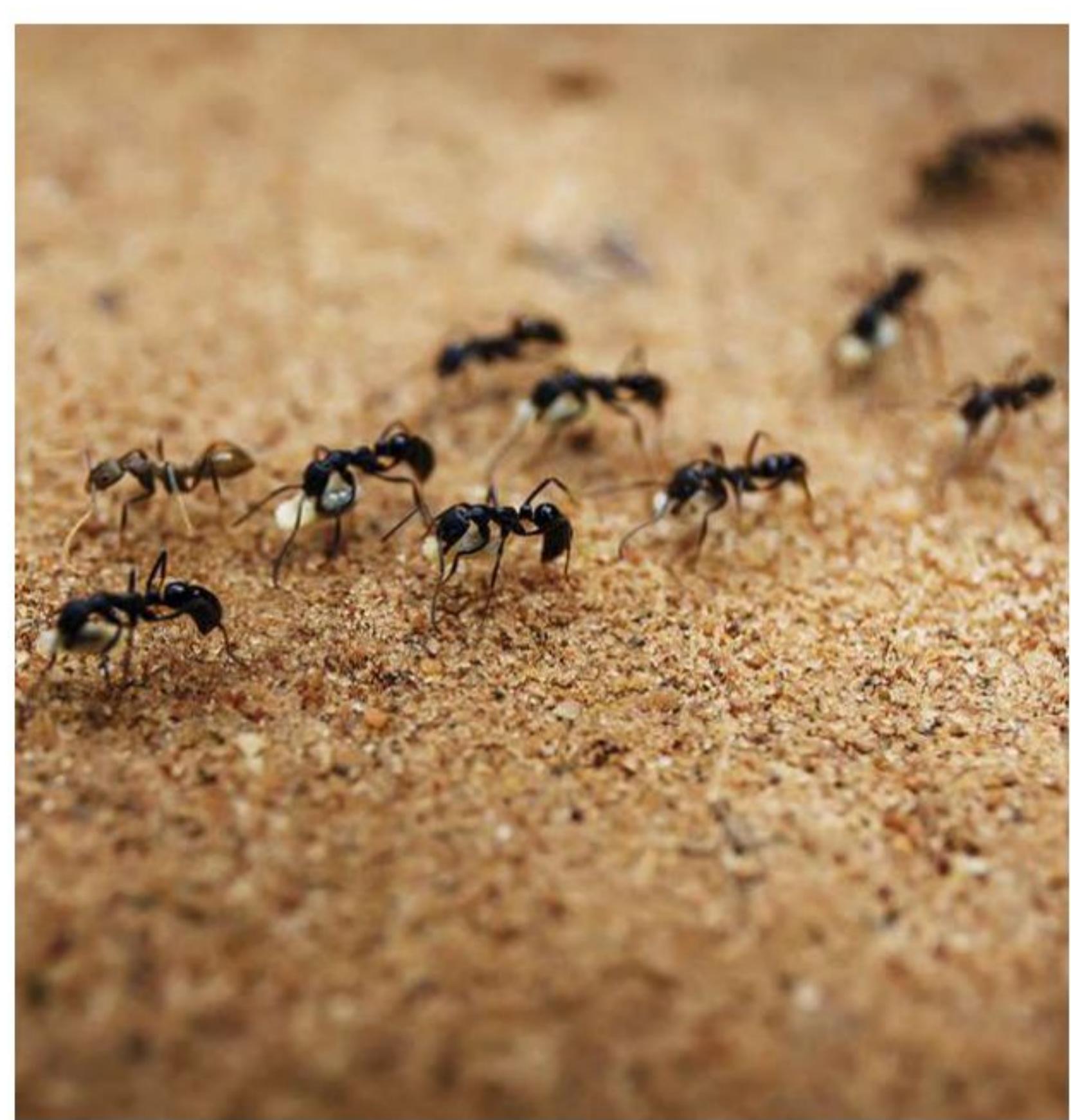


How else could we benefit?

Insects are a limitless source of inspiration. Take ants, for instance. These six-legged critters are brilliant navigators, foraging over large areas without getting lost. They do this by matching the 'views' seen during their route with those stored in their memory, allowing them to replicate a route they've travelled before. A collaborative UK project called Brains on Board is developing autonomous flying drones by translating ants' and other insects' visual systems into computer code. Current GPS systems rely on satellites, but these robots wouldn't need external guides to navigate, making them especially valuable for search and rescue missions where GPS can get cut off.



Nastaran Tavakoli-Far is the presenter of *Could Bees Take Over From Sniffer Dogs?* an episode of *CrowdScience*. It can be streamed at bit.ly/bees_crowd_science



Why do we sweat when we're anxious?

KANIKA AHUJA, WINCHESTER



This is part of our fight-or-flight response and happens when our sympathetic nervous system releases hormones, including adrenaline, which activates sweat glands. Brain scans reveal that sniffing someone else's panic-induced sweat lights up regions of the brain that handle emotional and social signals. So one theory is that this sweating is an evolved behaviour that makes others' brains more alert and primed for whatever it is that's making us anxious – handy if there's a marauding tiger on the loose. **ED**

QUESTION OF THE MONTH

Can weather forecasters predict rainbows?

JOHN, SOUTHAMPTON

A rainbow is created when sunlight splits into various colours as it enters raindrops. These rays then bounce off the interior and re-emerge at slightly different angles, depending on their colour. Seeing a rainbow thus depends on where you're standing relative to the Sun and the raindrops. So while forecasters can predict the conditions of patchy cloud and showery conditions that make a rainbow likely, they can't tell if you'll be in just the right place to see one. **RM**

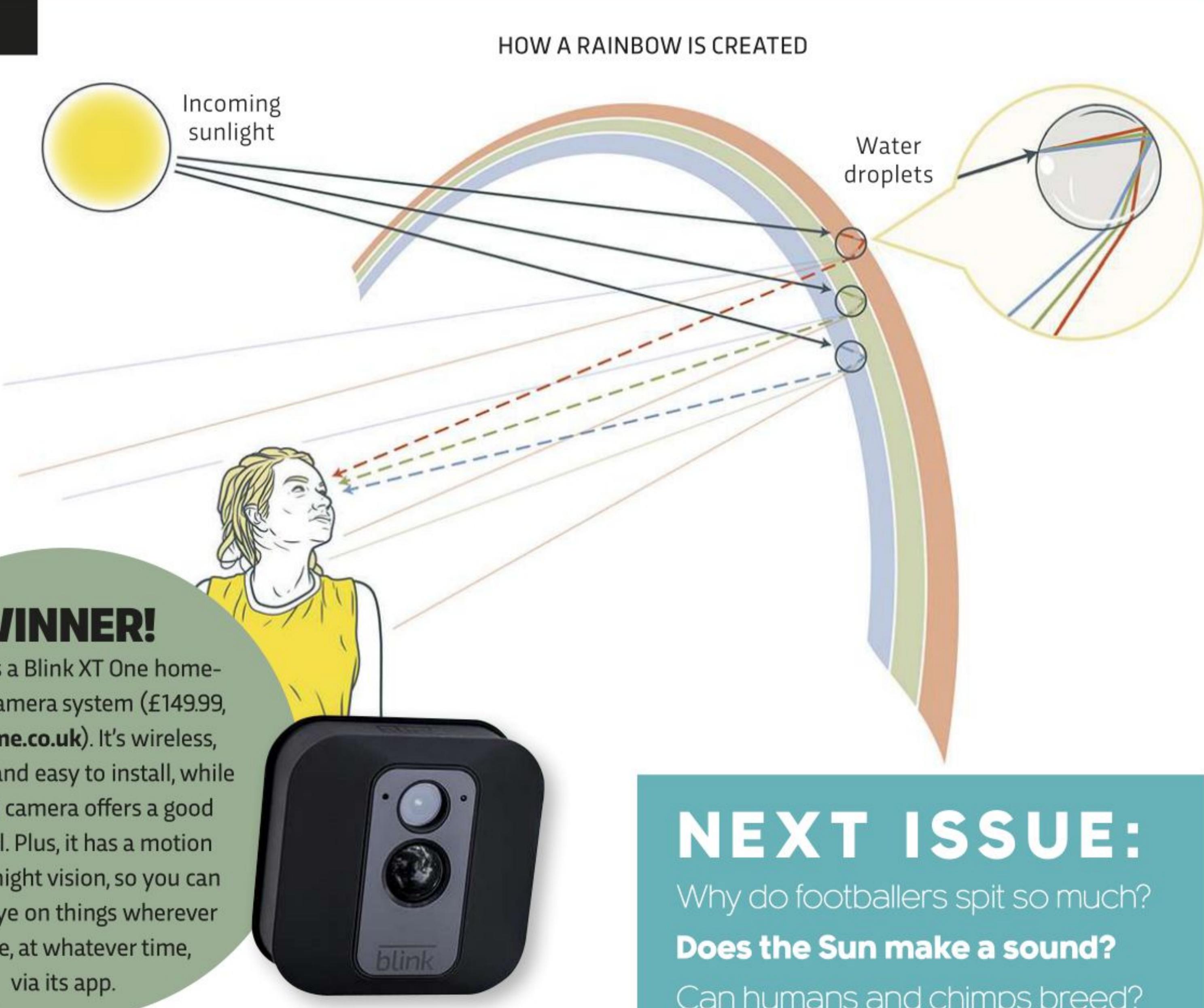


No, your Fruit Pastilles habit will not lead to glowing health

How many Fruit Pastilles would you need to eat to get one of your five-a-day?

OLIVIA BLACK, DERBY

Rowntree's Fruit Pastilles are flavoured with the concentrated juice of seven fruits, but the amount they contain is tiny. Figures from Nestlé (Rowntree's parent company) claim that 11.5 tubes of sweets have as much vitamin C as a portion of fruit. But the five-a-day campaign isn't really about vitamins – it's about fibre and eating a varied diet. Most people in the UK aren't deficient in vitamin C, and the NHS specifically says that vitamin pills don't count as your five-a-day. Those 11.5 tubes of Fruit Pastilles have no fibre and 2,125 calories – most of it sugar. **LW**



Email your questions to questions@sciencefocus.com or submit online at sciencefocus.com/qanda

OUT THERE

WHAT WE CAN'T WAIT TO DO THIS MONTH

AUGUST 2018

EDITED BY HELEN GLENNY



CONNOR STEFANISON



01

WONDER: SPECTACULAR
MOMENTS IN NATURE
PHOTOGRAPHY
OUT 7 AUGUST
(£26, CHRONICLE BOOKS)

WONDER AT THE WORLD

It was cold January morning, the final day of photographer Connor Stefanison's week-long trip to Yellowstone National Park. Mist swirled across the geothermal pools at Mammoth Hot Springs, while heat-tolerant algae and cyanobacteria transformed the colour of the rocks to shades of yellow, brown and green. The whole scene had an otherworldly feel, which inspired him to capture it in a photograph.

Stefanison's image seen here was one of the finalists in the California Academy of Sciences BigPicture Natural World Photography competition, and it's being showcased along with over 100 others in a new book called *Wonder: Spectacular Moments In Nature Photography*.

While the animal photographs capture those behaviours that humans don't often get to see, the landscape shots preserve transient moments in nature that might be missed by those without a photographer's eye. And if you're keen to recreate the images yourself, you'll be pleased to know that the book explains the scientific phenomena and photographic techniques behind each shot.

02

CLIMATE
STRANGE
MATT WINNING
EDINBURGH FRINGE
FESTIVAL
3-27 AUGUST

LIGHTEN UP ON THE CLIMATE

Environmental economist MATT WINNING focuses on climate change policy during the day – but he doesn't always take it seriously. In August he's taking his stand-up show, *Climate Strange*, to the Edinburgh Fringe Festival



Tell us about the show...

This is my second attempt to do a show about climate change. The last one was an overview: the science, the impact, the politics and the technology. This one is from an individual point of view – it's about what we can do about climate change and why we're not doing it yet.

So what can we do?

A paper last year named the top four things you could do to reduce your impact, which included reduce your meat consumption, fly less and don't drive. The number one thing was to not have any children.

So the best thing you can possibly do for your children's

future is to not have any children. It's interesting juxtaposition, especially as my girlfriend and I are planning on having a child very soon. So what can you do? How do you offset having a child? I work in this area and I'm trying to reduce my carbon footprint and get others to reduce theirs, but also at the same time I do the same things and have the same aspirations as everyone else.

You talk about the psychology of climate change in the show. What is that?

There's literature out there about why people ignore, deny or don't engage with climate change. Over the last 20 to 30 years the tactic has been to tell people things, and if

that doesn't work tell them more, give them more facts. If anything, this backfires.

You get a newspaper headline that says '75 per cent of people don't recycle', then that makes us think 'oh, well, nobody else recycles so I'm not going to bother'. There's a way of framing it. If a hotel says three-quarters of guests hang up and reuse their towels, then most people start doing it, because it's normal to want to be part of the consensus.

I think that the psychological and behavioural aspects are now the key to us trying to solve climate change from a personal perspective.

So are you employing these psychological tactics in your stand-up?

Oh yeah, of course! I'm trying to do as much as I possibly can. I'll talk about the hurricanes or fires that happened last year, and the facts about solar and wind power that are coming in. Climate change can often feel like a distant subject, with a focus on what's going to happen at the end of the century, but people stop dismissing it if you make it more present.

It's a heavy topic – why tackle it with comedy?

It's a way of engaging different types of people, which is really important. It's heavy, and people often shut themselves off from it, but using comedy means people can enjoy themselves, and they'll ingest some facts about it. And from a personal point of view, it makes me feel less depressed.



03

SEE SOME ACTION

ACTION REPLAY
NATIONAL SCIENCE
AND MEDIA MUSEUM,
BRADFORD
UNTIL 30 SEPT 2018

With the video-assistant referee inciting debates this summer, and tennis slo-mo all over the news, the National Science and Media Museum is going behind the scenes with *Action Replay*, an exhibition about game-changing tech in sports broadcasting.

It highlights breakthroughs, like the role of Wimbledon and snooker in introducing colour TV in the 1960s, right through to more recent freeze frames, action replays and 'ref cams'.

It even offers you the chance to direct sports replays in slow motion, and find out whether you can match a commentator's speed of thought. The exhibition also takes a look at some more unusual icons from the broadcasting world, including Paul the psychic octopus, the 'cheat sheets' used by BBC Radio Newcastle's Sunderland football commentator Nick Barnes, and the Telestrator light pen used to draw on-screen graphics.



04

POWER UP
MUSEUM OF SCIENCE
AND INDUSTRY,
MANCHESTER
3-19 AUGUST 2018

GO GAMING

Indulge your inner child with the past, present and future of gaming at the *Power UP* exhibition at Manchester's Museum of Science and Industry.

You'll find games consoles like the SNES and SEGA Dreamcast sitting alongside modern PS4s and Xbox Ones, and for a glimpse into the future of gaming, you can try out modern innovations like the Playstation VR. In total, there are over 160 consoles on offer, featuring some of the most popular games from the past 40 years, including *Pong*, *Pac-Man*, *Minecraft* and *Super Mario*. For big kids, there are a few adults-only evening sessions.

Somewhere in a parallel universe, there's a giant frog licking the back of a small child. We wouldn't recommend doing either...



05 WALK ON THE WILD SIDE

PROJECT WILD THING

BBC iPLAYER,
UNTIL 4 SEPTEMBER

According to a UNICEF report, children in the UK and USA are among the least happy in the world. Research shows that children are happiest when playing in nature. Determined to get his children into the great outdoors and off their screens, filmmaker David Bond appointed himself marketing director for Mother Nature. He had to compete with the likes of Apple, Disney and Mattel for his kids' attention.

Project Wild Thing is the story of David's attempt to fix his kids' disconnection from the outdoors, gradually reintroducing them to the wild, and is free to watch on iPlayer until 4 September. Here are our favourite wild activities to enjoy with your family in the sunshine.

1. BUILD A WILD DEN

Use sticks and branches to build the frame of your den, then cover it with leaves or blankets.

2. ROLL DOWN A HILL

Rolling down hills never gets old – and all you need is a grassy slope and a bit of recklessness.

3. HOST A NATURE COCKTAIL PARTY

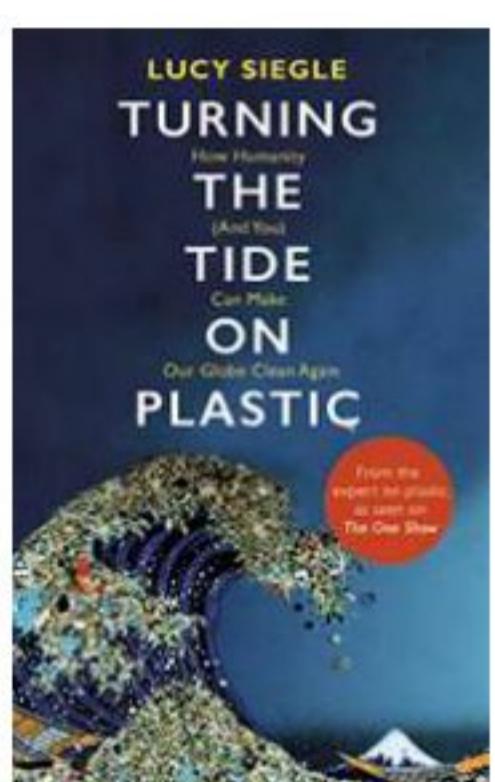
Seek out an area with lots of plants, and find the ones that smell best. Break them between your fingers and pop them into an old container, and let your friends have a smell.

4. TELL THE TIME USING THE SUN

Place a stick in the ground so it stands upright in a sunny spot that you can return to throughout the day. Every hour, place a numbered rock where the stick's shadow is, and you'll have made a natural sundial.

5. MAKE SEASHELL ART

Head to the beach, collect a few different seashells (make sure nobody is living inside them) and driftwood. Take them home and thread them into necklaces or use to decorate photo frames or boxes.



06 REDUCE PLASTIC

TURNING THE TIDE ON PLASTIC
BY LUCY SIEGLE
OUT 26 JULY
 (£12.99, ORION BOOKS)

LUCY SIEGLE has travelled the world cleaning beaches and talking to manufacturers, policy makers and environmentalists about the plastic pandemic. Here are five top tips from her new book...



1. SWITCH TO SOAP BARS

Many liquid soap bottles don't make it into recycling because they are made from strange and difficult plastics, and some contain extra pumps and complicated dispensers. Move back to a bar of soap, and for some extra brownie points, buy an eco-friendly soap wrapped in paper rather than a plasticised wrapper.



2. WEAN YOURSELF OFF WET WIPES

Wet wipes contain plastic polymers that, along with cotton buds and contact lenses, cannot always be recovered in our wastewater treatment plants. Instead, they escape into our waterways with devastating consequences for the environment.

Conservationists in London recently found just under 5,500 wet wipes that had amassed and congealed to form a bank in the bed of the Thames. Switch to an old-fashioned damp flannel.

3. USE MUSHROOM BAGS FOR LOOSE VEGETABLES

At the supermarket, you can avoid plastic in the vegetable aisle by picking the loose fruit and veggies. Not all fruit and veg can be brought to the checkout completely loose, so nab some of the paper mushroom bags for things you buy in bulk, like salad potatoes, tomatoes and radishes.



4. TAKE INSPIRATION FROM LOCAL HEROES

Plastic warrior Dan Thompson spotted a plethora of abandoned buckets and spades in Margate following a sunny bank holiday, so he made a large wooden box and decanted the beach toys into them. Now visitors to the seaside can borrow a bucket and spade from the Bucket Box at The Bus Café instead of buying new ones. It's a local solution from which we can all take inspiration.



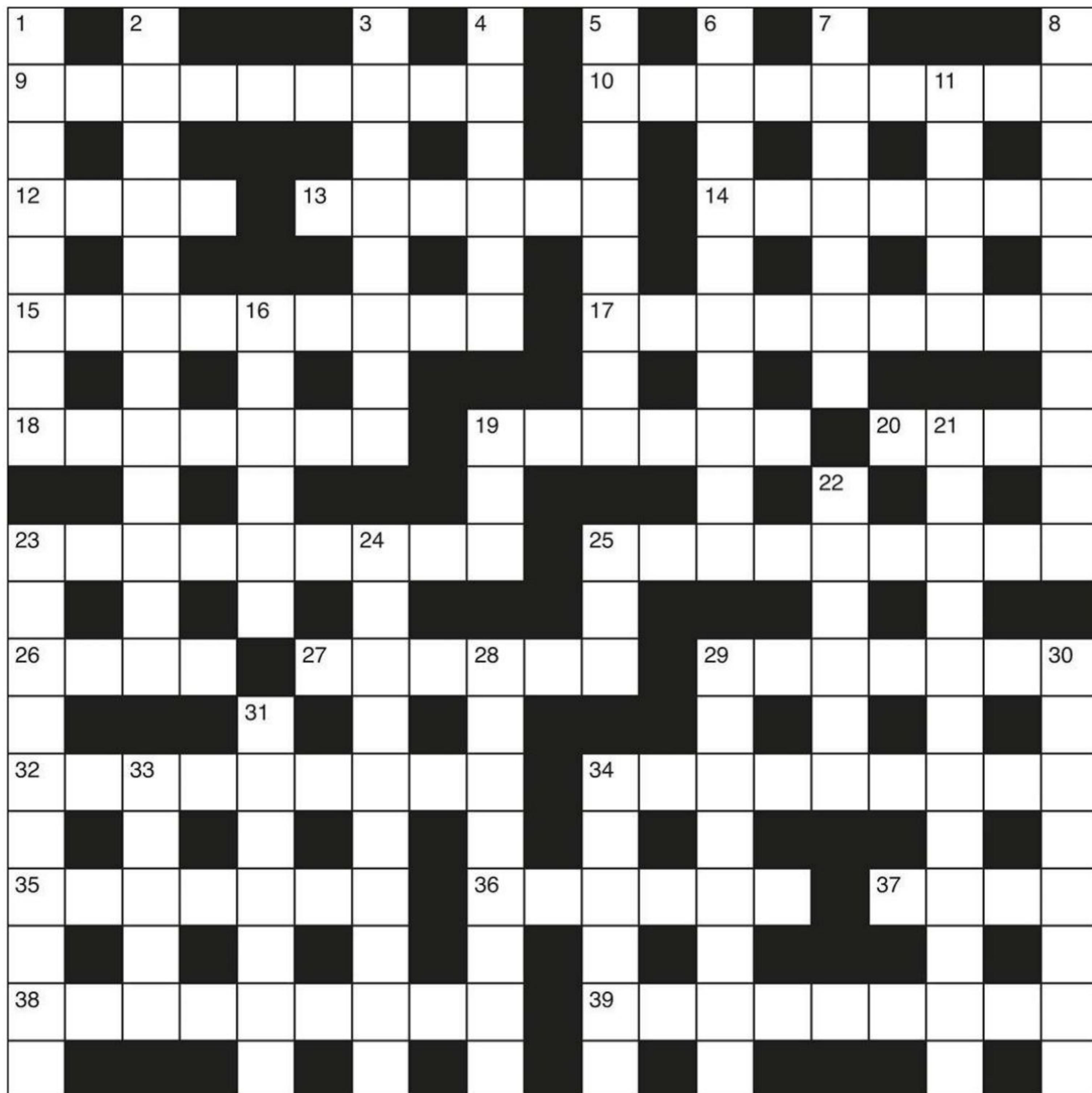
5. RELOCATE TO WALES

If you want to up your recycling rate, head westwards. England, Scotland and Northern Ireland don't appear among the top 10 world leaders in recycling, but Wales comes in second (narrowly beaten to the top spot by Germany).

Rather than shoving everything into one green 'mixed' recycling bin, Welsh residents sort recycling at home into lots of different boxes. The system results in higher quality recycling, which is easier to sell into the global market.

BBC FOCUS CROSSWORD

GIVE YOUR BRAIN A WORKOUT



DOWN

- Play a triad, alternatively, on bit of plumbing (8)
- Understanding small wine brings disorientation (7,5)
- Scheme ain't working to get a vegetable (8)
- Minced for a reason (6)
- Artist mixes cuts to get record – gold (8)
- Old creature set out urban roots (10)
- Aristocrat of the French game (7)
- Earl somehow less sensitive – not an imaginary figure (4,6)
- Bird can be found in rocky creak (5)
- Almost dull on Neptunian moon (6)
- Percussion instrument heard to make some sound (3)
- Eli sits alone distilling aroma compound (9,3)
- Initially bully everyone to affect the voting (6)
- Errand boy gets recent change in proportion (10)
- Destinies interwoven with a part of S Asia (4,6)
- Encountered the police in London (3)
- Large number of people initially failed the oral (8)
- Principal supporter to stop on the other side of the sea (4,4)
- Graduate has need to run round to get a worm (8)
- Diamonds put in air to give some dimension (7)
- Writer joins church for money (5)
- Emphasise anxiety (6)

ACROSS

- Kindly make lava run in a fluid way, containing copper (9)
- Worry about group not completing large gem (9)
- I return to a tiny amount (4)
- Plant book (6)
- Aztec to haunt a construction by lake (7)
- Jog with a strange fellow – The Fool, possibly (5,4)
- Bridal gear to use as tour develops (9)
- Two chaps from eastern Europe (7)
- Treasurer finds ours didn't start in pub (6)
- Rosemary may be found in another book (4)
- Picture room for light device (9)
- Duck as germs are spread with tip of nose (9)
- Playboy leaves – they're taken by it (4)
- Has resolved – mine is found under grate (3-3)
- Woman swaps end with new pigment (7)
- Old exercise tries to improve proficiency (9)
- Religion is not his new medium (9)
- Mug puts vehicle on a road (7)
- That woman's easy answer is lacking dissent (6)
- Stomach has large surplus (4)
- Wonderful to tolerate a bunch of stars (5,4)
- Germanic hero is back, say, exhausted (9)

ANSWERS

For the answers, visit
bit.ly/BBCFocusCW
 Please be aware the website address is case-sensitive.



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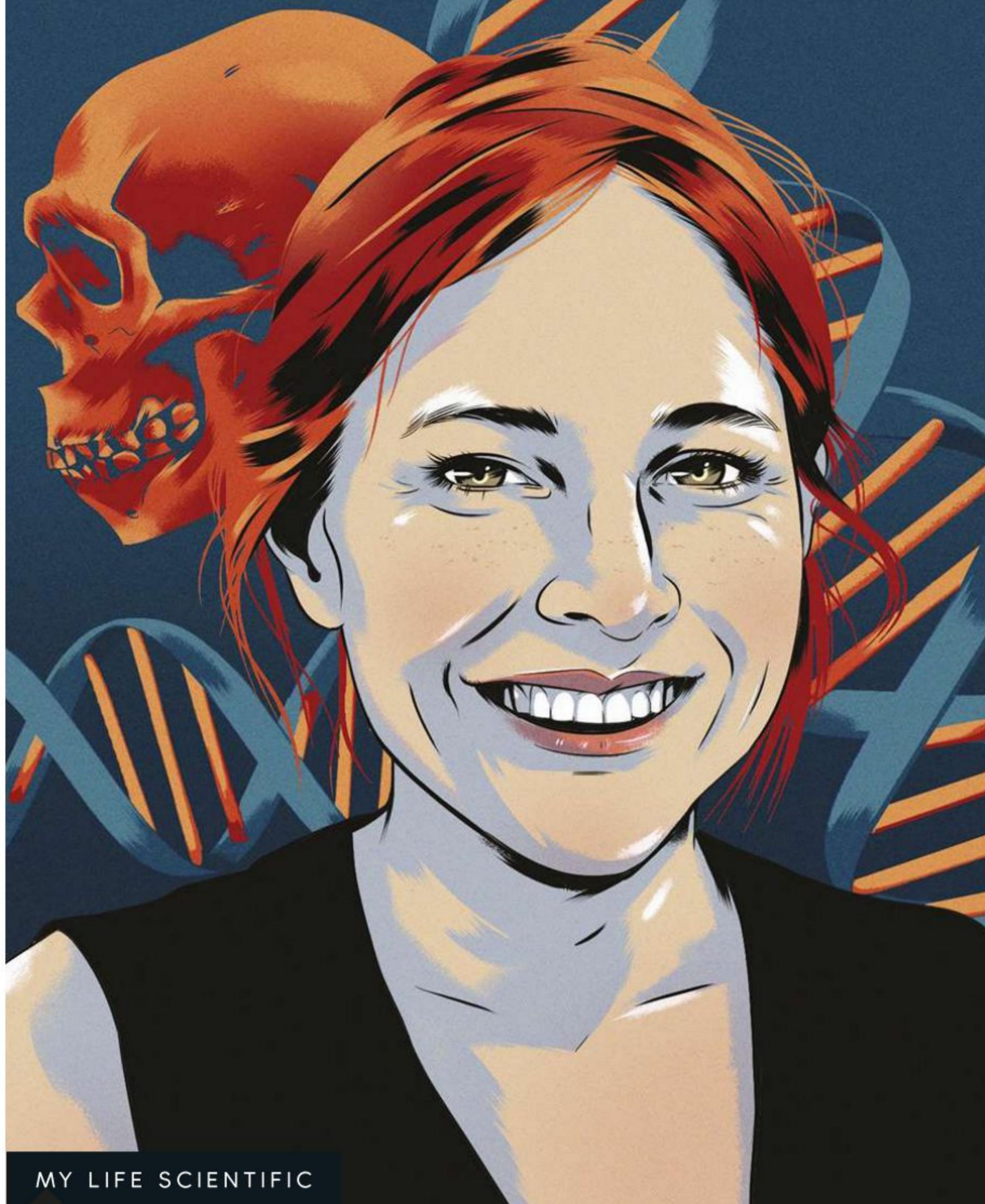
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MY LIFE SCIENTIFIC

Dr Alice Roberts

This month, anatomist and presenter **Alice Roberts** talks to **Helen Pilcher** about her love of skeletons and the lure of *Strictly Come Dancing*

Alice's favourite programme she's worked on is *Wild Swimming*. Her wildest swim took her into a pitch-black cave in Derbyshire.

Which extinct species would you most like to meet?

Neanderthals. They are our closest relative. We try to reconstruct the minds of these people by looking at their culture. I'd like to know how different they were to modern humans from the same time.

Who would win in a fight – a Neanderthal or a modern human?

If it's about brawn then probably a Neanderthal. They were, on average, more muscly than Palaeolithic modern humans. We know this from the size and shape of their bones, and

can reconstruct their muscle mass from that. But they might have had sex rather than fight.

Ah yes, early humans and Neanderthals interbred...

...which means anyone of broadly European or Asian descent has a bit of Neanderthal DNA tucked away in them. I'm 2.7 per cent Neanderthal, which is more Neanderthal than comedian Bill Bailey. [Alice and Bill both had a DNA test.]

Best moment of your career?

Passing my PhD viva. They go off and have a little conflagration and leave you

sitting there wondering what's going on. Then they call you back in and stare at you and say 'you've done it'. My PhD was in the study of disease in ancient human remains.

What led you away from research?

People often ask me how I got started in TV and the answer, genuinely, is by mistake. My husband had a friend who was working on *Time Team*. They asked me to do post-excavation reports on the skeletons at their digs, then kept inviting me back. After that, other TV work followed.

Is it true that you'd like to do *Strictly*?

I would. I'm not very good at dancing but I'd really like the challenge and I would definitely take it seriously.

Tell me a surprising fact about human bones...

If you go back in evolutionary history, the collar bone or 'clavicle' was part of the attachment of the fish's fin to the skull. Also, the human skeleton turns over [replaces itself] every 7 to 10 years. We think of bones as being dead and static, but they're dynamic, living things.

Favourite archaeological site?

Göbekli Tepe in Turkey. It's an 11,000-year-old temple site with massive stone megaliths, T-shaped pillars arranged in circles, and exquisite animal carvings. They're extraordinarily beautiful and evidence that complex beliefs and stratified society were emerging earlier than previously thought.

One message for our readers?

It's never too late to be interested in science. Read about it. Listen to science programmes. Watch science films. There's joy in that knowledge. It can help you understand the world around you, help you make better choices, and it's really, really fun. **F**

Dr Alice Roberts is an anatomist, writer and presenter. Her latest book is *Tamed: Ten Species That Changed Our World* (£20, Hutchinson).

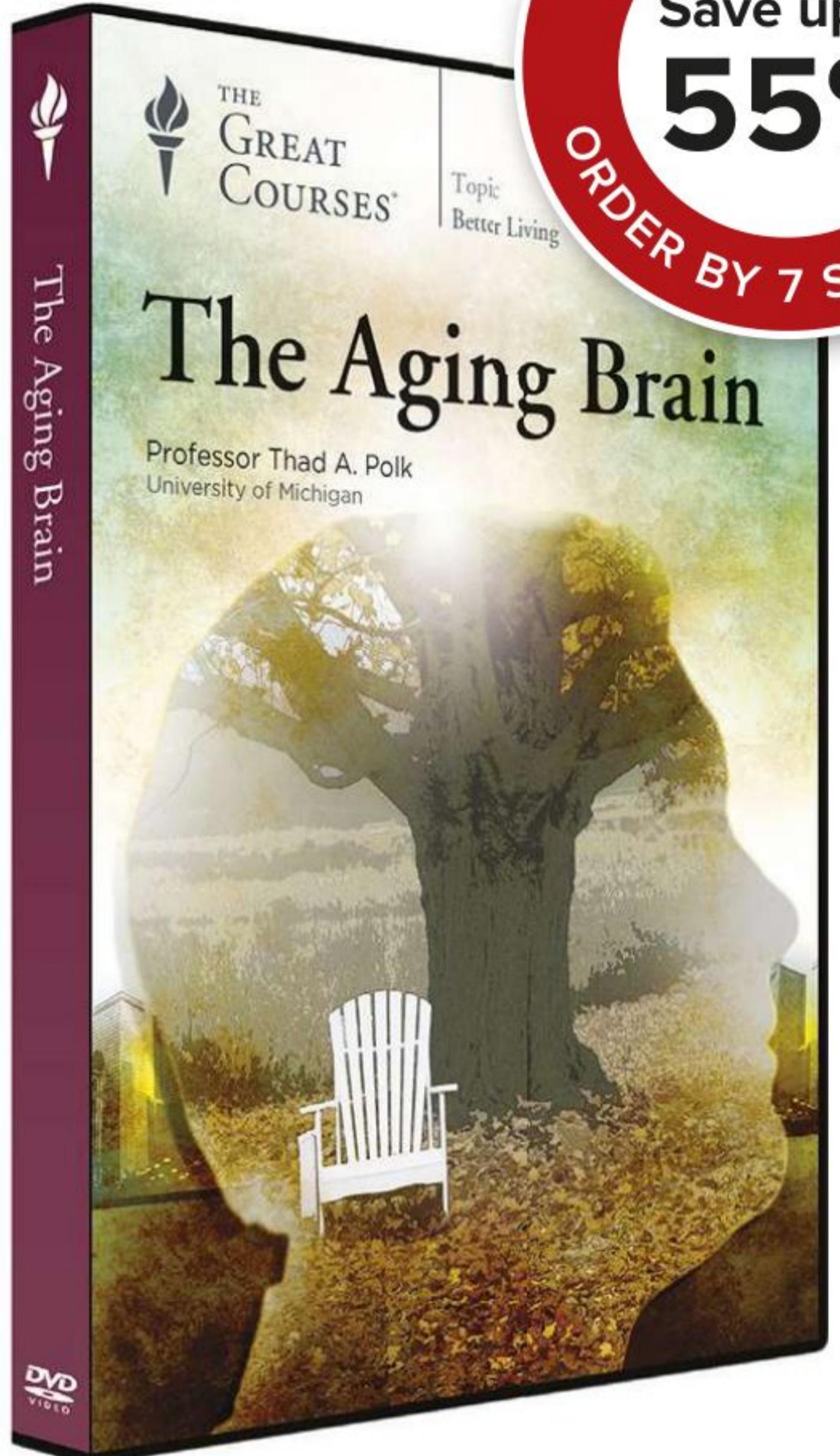
DISCOVER MORE



To listen to episodes of *The Life Scientific* with top scientists, visit bit.ly/life_scientific

NEXT ISSUE: ELLA AL-SHAMAHY

"I'M 2.7 PER CENT NEANDERTHAL, WHICH IS MORE NEANDERTHAL THAN COMEDIAN BILL BAILEY"



Learn How to Keep Your Mind Healthy

Growing older may be inevitable, but there is much you can do to fight senility. By studying communities where people tend to live exceptionally long lives, using brain scanning technologies such as fMRIs, and conducting longitudinal studies of the population, researchers have uncovered a wealth of information about staying healthy and keeping your mind sharp.

Taught by Professor Thad Polk, a neuroscientist and award-winning professor at the University of Michigan, these twelve eye-opening lectures will give you new insights into what happens to the brain over time—as well as strategies to mitigate the effects of aging and enhance your quality of life into old age. Mixing scientific research and practical applications, Professor Polk brings cutting-edge science to life. He takes you down to the cellular and even molecular level of the brain to teach you what you can do to prolong your health and keep your mental edge. Aging affects us all, but as you will learn in *The Aging Brain*, you have some control over how it affects you.

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